# THE IMPACTS OF IMPROVING BRAZIL'S TRANSPORTATION INFRASTRUCTURE ON THE WORLD SOYBEAN MARKET

A Thesis

by

RAFAEL DE FARIAS COSTA

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2007

Major Subject: Agricultural Economics

# THE IMPACTS OF IMPROVING BRAZIL'S TRANSPORTATION INFRASTRUCTURE ON THE WORLD SOYBEAN MARKET

A Thesis

by

RAFAEL DE FARIAS COSTA

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Approved by:

Chair of Committee, C. Parr Rosson, III
Committee Members, Stephen W. Fuller
Travis D. Miller
James W. Richardson
Head of Department, John Nichols

December 2007

Major Subject: Agricultural Economics

## ABSTRACT

The Impacts of Improving Brazil's Transportation Infrastructure on the World Soybean Market. (December 2007)

Rafael de Farias Costa, B.S., Federal University of Pernambuco

Chair of Advisory Committee: Dr. C. Parr Rosson, III

The lack of adequate transportation infrastructure in Brazil has been a bottleneck for the soybean producers for many years. Moreover, the costly inland transportation incurred from this bottleneck has resulted in a loss in competitiveness for Brazil compared to other exporting countries, especially the United States. If transportation costs are reduced by introducing improved infrastructure, Brazil is expected to increase its competitiveness in the world soybean market by increasing its exports and producer revenues. On the other hand, the United States and other significant soybean competing exporting countries are expected to lose market share as well as producer revenues.

This study uses a spatial equilibrium model to analyze transportation infrastructure improvements proposed by the Brazilian government vis-à-vis enhance the nation's soybean transportation network. The analyzed transportation improvements are: (i) the development of the Tapajós-Teles Pires waterway; (ii) the completion of the BR-163 highway; (iii) the construction of the Mortes-Araguaia waterway; (iv) the Ferronorte railroad expansion to Rondonópolis and the linkage between the city of Rio Verde to Uberlândia; and (v) the Ferropar railroad expansion to the city of Dourados. The model specifies the Brazilian inland transportation network and the international ocean

shipments. The model divides Brazil into 18 excess supply regions and 8 excess demand regions. The competing exporting countries are the United States, Argentina, Rest of South America (Bolivia, Paraguay, and Uruguay), Canada, and India. The importing countries are composed of China, European Union, Southeast Asia, Mexico, and the Rest of the World.

Results suggest these proposed transportation improvements yield potential noteworthy gains to Brazil with producer revenues increasing more than $500 million and exports increasing by 177 thousand metric tons. Consequently, the world soybean price declines by $1.16 per metric ton and producer revenues and exports in the United States fall by 63 thousand metric tons and $104.89 million, respectively. Although the absolute gains in price, revenues, and exports for Brazil are considerable, they only represent in relative changes 1.48, 2.35, and 0.32 percent, respectively. Similarly, the loss in price, revenue, and export value for the United States is also low, declining by 0.23, 0.23, and 0.12 percent, respectively.

# DEDICATION

To my parents, Ecio and Vera, and my brothers, Ecio, Diogo, Thiago

## ACKNOWLEDGEMENTS

I would like to thank my committee chair, Dr. C. Parr Rosson, and my committee members, Dr. Steve Fuller, Dr. James Richardson, and Dr. Travis Miller, for their orientation and support throughout the course of this work.

Thanks also to my friends and colleagues at the Center for North American Studies, with special thanks to Flynn Adcock and Xia Yan, and the Department of Agricultural Economics. I also want to extend my gratitude to classmates who were supporting me during class and research hours. Special thanks to Luis Fellin for collaborating on the methodological part of my work, specially the programming part.

Finally, thanks to my parents and brothers, without them, my experience here in Texas A&M University would not have come true.

# TABLE OF CONTENTS

Page

## LIST OF FIGURES

# LIST OF TABLES

Page

Page

# CHAPTER I

# INTRODUCTION

This introduction is composed of a brief discussion of the world soybean market, the soybean market in Brazil, the export cost competitiveness between the three leading exporting countries: United States, Brazil, and Argentina, objectives and procedures. The primary purpose of this thesis is to examine the extent to which improvements in transportation infrastructure in Brazil would affect the local soybean industry and the competitive position of other soybean exporting countries.

## World Soybean Market

Since the 1960's, the United States has been the world's leading soybean producer and exporter. Since then, the U.S. share of production and exports share has declined from over 50 percent and 60 percent in 1990/91, respectively, to approximately 38 percent and 40 percent in 2006/07, respectively. This loss of production and export share is partly due to soybean sector expansion in Brazil and Argentina. Tables 1 and 2 show that South American countries have been gaining share in both production and exports of soybeans in the world market. Between 1990/91 and 2006/07, Brazil and Argentina had an average production growth rate of 8.58 percent and 9.90 percent, respectively. Meanwhile the United States had an average growth rate of four percent. As for exports, the average growth rates of Brazil and Argentina for the same period

---

This thesis follows the style of the *American Journal of Agricultural Economics*.

were 20.58 percent and 20.41 percent, respectively, compared to only a 5.76 percent average growth for the United States.

**Table 1. World Soybean Production in Million Metric Tons (MMT), Marketing Years 1990/1991 – 2006/2007**

| Country | U.S. | | Brazil | | Argentina | | World | |
|---|---|---|---|---|---|---|---|---|
| MY | MMT | %-ch. | MMT | %-ch. | MMT | %-ch. | MMT | %-ch. |
| 90/91 | 52.42 | - | 15.75 | - | 11.50 | - | 104.29 | - |
| 91/92 | 54.07 | 3.15 | 19.30 | 22.54 | 11.35 | -1.30 | 107.55 | 3.13 |
| 92/93 | 59.61 | 10.26 | 22.50 | 16.58 | 11.35 | 0.00 | 117.38 | 9.14 |
| 93/94 | 50.89 | -14.64 | 24.70 | 9.78 | 12.40 | 9.25 | 117.77 | 0.33 |
| 94/95 | 68.44 | 34.51 | 25.90 | 4.86 | 12.50 | 0.81 | 137.78 | 16.99 |
| 95/96 | 59.17 | -13.54 | 24.15 | -6.76 | 12.48 | -0.16 | 125.05 | -9.23 |
| 96/97 | 64.78 | 9.47 | 27.30 | 13.04 | 11.20 | -10.26 | 132.30 | 5.80 |
| 97/98 | 73.18 | 12.96 | 32.50 | 19.05 | 19.50 | 74.11 | 158.24 | 19.60 |
| 98/99 | 74.60 | 1.94 | 31.30 | -3.69 | 20.00 | 2.56 | 160.06 | 1.15 |
| 99/00 | 72.22 | -3.18 | 34.70 | 10.86 | 21.20 | 6.00 | 160.63 | 0.36 |
| 00/01 | 75.06 | 3.92 | 39.50 | 13.83 | 27.80 | 31.13 | 176.00 | 9.57 |
| 01/02 | 78.67 | 4.82 | 43.50 | 10.13 | 30.00 | 7.91 | 185.09 | 5.17 |
| 02/03 | 75.01 | -4.65 | 52.00 | 19.54 | 35.50 | 18.33 | 197.03 | 6.45 |
| 03/04 | 66.78 | -10.97 | 51.00 | -1.92 | 33.00 | -7.04 | 186.77 | -5.21 |
| 04/05 | 85.01 | 27.31 | 53.00 | 3.92 | 39.00 | 18.18 | 215.95 | 15.62 |
| 05/06 | 83.37 | -1.93 | 55.00 | 3.77 | 40.50 | 3.85 | 218.04 | 0.96 |
| 06/07 | 86.77 | 4.08 | 56.00 | 1.82 | 42.50 | 4.94 | 226.85 | 4.04 |
| Average | 70.48 | 3.97 | 37.02 | 8.58 | 23.77 | 9.89 | 163.91 | 5.24 |

*Source*: Foreign Agricultural Service/USDA (FAS/USDA, 2007a).

**Table 2. World Soybean Exports in Million Metric Tons (MMT), Market Years 1990/1991 – 2006/2007**

| Country | U.S. | | Brazil | | Argentina | | World | |
|---|---|---|---|---|---|---|---|---|
| MY | MMT | %-ch. | MMT | %-ch. | MMT | %-ch. | MMT | %-ch. |
| 90/91 | 15.16 | - | 2.48 | - | 4.47 | - | 25.40 | - |
| 91/92 | 18.61 | 22.78 | 3.87 | 56.26 | 3.21 | -28.10 | 28.10 | 10.61 |
| 92/93 | 20.97 | 12.67 | 4.06 | 4.75 | 2.21 | -31.19 | 29.30 | 4.26 |
| 93/94 | 16.01 | -23.68 | 5.43 | 33.97 | 3.02 | 36.73 | 27.73 | -5.35 |
| 94/95 | 22.87 | 42.87 | 3.57 | -34.38 | 2.58 | -14.62 | 31.98 | 15.34 |
| 95/96 | 23.11 | 1.05 | 3.46 | -3.03 | 2.10 | -18.52 | 31.64 | -1.06 |
| 96/97 | 24.11 | 4.34 | 8.42 | 143.61 | 0.76 | -64.00 | 36.76 | 16.18 |
| 97/98 | 23.76 | -1.45 | 8.76 | 3.99 | 3.17 | 318.89 | 39.63 | 7.79 |
| 98/99 | 21.90 | -7.84 | 8.93 | 1.95 | 3.40 | 7.32 | 38.27 | -3.43 |
| 99/00 | 26.54 | 21.18 | 11.10 | 24.30 | 4.13 | 21.28 | 45.63 | 19.22 |
| 00/01 | 27.10 | 2.13 | 15.47 | 39.35 | 7.41 | 79.65 | 53.87 | 18.07 |
| 01/02 | 28.95 | 6.81 | 15.00 | -3.03 | 6.00 | -19.02 | 53.44 | -0.81 |
| 02/03 | 28.42 | -1.81 | 19.73 | 31.56 | 8.71 | 45.14 | 61.18 | 14.49 |
| 03/04 | 24.13 | -15.11 | 19.82 | 0.42 | 6.93 | -20.52 | 55.80 | -8.79 |
| 04/05 | 29.86 | 23.76 | 20.14 | 1.61 | 9.31 | 34.45 | 64.54 | 15.65 |
| 05/06 | 25.78 | -13.67 | 25.90 | 28.63 | 7.26 | -22.01 | 64.43 | -0.17 |
| 06/07 | 30.48 | 18.25 | 25.75 | -0.58 | 7.35 | 1.21 | 70.20 | 8.96 |
| Average | 23.99 | 5.77 | 11.88 | 20.59 | 4.83 | 20.42 | 44.58 | 6.94 |

*Source*: Foreign Agricultural Service/USDA (FAS/USDA, 2007a).

Table 3 shows that China and the European Union (EU) are the leading soybean importers for the last five years. Although China is the largest soybean importer in the world, in the early nineties, China was self-sufficient. China has consistently been one of the top soybean producers in the world with 16.2 million metric tons (MMT) for 2006/07. After China's accession into the World Trade Organization (WTO) in December 2001, Chinese soybean imports increased from 10.39 MMT in 2001/02 to 31.50 MMT in 2006/07. The EU has maintained stable imports with a growth rate of

1.10 percent annually. The EU has rigid sanitary and phytosanitary measures, which limit the import of certain genetically modified soybeans. Therefore, Brazil gains from such measures because most of Brazilian soybeans are not genetically modified while most of the United States and Argentina crops are. The United States and Argentina have approximately 88 and 98 percent of their crops as Roundup Ready soybeans, respectively. It is estimated that one third of Brazil's soybean crop was genetically modified in 2005 (Kalaitzandonakes, 2006).

**Table 3. World Soybean Importers in Million Metric Tons (MMT), Market Years 1990/1991 – 2006/2007**

| Country | China | | EU | | ROW | | World | |
|---|---|---|---|---|---|---|---|---|
| MY | MMT | %-ch. | MMT | %-ch. | MMT | %-ch. | MMT | %-ch. |
| 90/91 | 0.00 | - | 12.99 | - | 12.56 | - | 25.55 | - |
| 91/92 | 0.14 | - | 13.48 | 3.81 | 14.60 | 16.28 | 28.22 | 10.47 |
| 92/93 | 0.15 | 10.29 | 14.92 | 10.65 | 14.98 | 2.58 | 30.05 | 6.47 |
| 93/94 | 0.13 | -16.67 | 12.98 | -12.97 | 15.07 | 0.60 | 28.18 | -6.22 |
| 94/95 | 0.16 | 24.00 | 16.23 | 25.00 | 16.38 | 8.68 | 32.76 | 16.27 |
| 95/96 | 0.80 | 412.90 | 14.53 | -10.50 | 17.14 | 4.66 | 32.46 | -0.92 |
| 96/97 | 2.27 | 186.04 | 14.57 | 0.32 | 18.79 | 9.60 | 35.63 | 9.77 |
| 97/98 | 2.94 | 29.29 | 15.14 | 3.88 | 20.09 | 6.96 | 38.17 | 7.12 |
| 98/99 | 3.85 | 30.95 | 14.86 | -1.84 | 20.63 | 2.67 | 39.34 | 3.06 |
| 99/00 | 10.10 | 162.34 | 14.13 | -4.91 | 21.97 | 6.47 | 46.19 | 17.42 |
| 00/01 | 13.25 | 31.14 | 17.53 | 24.04 | 22.39 | 1.92 | 53.16 | 15.07 |
| 01/02 | 10.39 | -21.59 | 18.54 | 5.79 | 25.59 | 14.31 | 54.52 | 2.55 |
| 02/03 | 21.42 | 106.23 | 16.87 | -8.99 | 24.82 | -3.01 | 63.11 | 15.76 |
| 03/04 | 16.93 | -20.94 | 14.64 | -13.24 | 22.49 | -9.40 | 54.06 | -14.34 |
| 04/05 | 25.80 | 52.38 | 14.54 | -0.64 | 23.36 | 3.88 | 63.71 | 17.85 |
| 05/06 | 28.32 | 9.75 | 13.93 | -4.19 | 21.75 | -6.91 | 64.00 | 0.46 |
| 06/07 | 31.50 | 11.24 | 14.14 | 1.46 | 23.49 | 8.02 | 69.13 | 8.02 |
| Average | 9.89 | 67.16 | 14.94 | 1.10 | 19.77 | 4.21 | 44.60 | 6.80 |

*Source*: Foreign Agricultural Service/USDA (FAS/USDA, 2007a).

With respect to soybean (oilseed) consumption or use, the crushing industry is the initial user in most producing and importing countries. Table 4 shows the consumption and crushing in the United States, Brazil, Argentina, China, and the EU. Historically, the United States is the largest consumer and crusher in the world. However, Brazil, Argentina, and China have doubled their consumption and crushing throughout the years. In most of these latter countries, soybean consumption is represented by the crushing industry, with the exception of China where human consumption is common.

**Table 4. Total Consumption and Crushing by Country in Million Metric Tons (MMT), Market Years 1990/1991 – 2006/2007**

| MY | U.S. | | Brazil | | Argentina | | China | | EU | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Cons. | Crush | Cons. | Crush | Cons. | Crush | Cons. | Crush | Cons. | Crush |
| 90/91 | 34.90 | 32.31 | 15.41 | 14.20 | 7.45 | 6.98 | 9.71 | 3.90 | 14.98 | 12.93 |
| 91/92 | 36.92 | 34.13 | 16.20 | 14.94 | 8.23 | 7.75 | 8.76 | 3.39 | 15.44 | 13.50 |
| 92/93 | 38.32 | 34.81 | 16.98 | 15.55 | 9.02 | 8.53 | 10.15 | 4.49 | 16.49 | 14.45 |
| 93/94 | 37.32 | 34.72 | 20.05 | 18.44 | 9.31 | 8.78 | 14.34 | 7.61 | 14.18 | 12.68 |
| 94/95 | 42.31 | 38.24 | 21.84 | 20.15 | 9.25 | 8.70 | 15.76 | 8.59 | 17.34 | 15.40 |
| 95/96 | 40.31 | 37.27 | 23.24 | 21.70 | 10.83 | 10.26 | 14.07 | 7.47 | 15.77 | 14.34 |
| 96/97 | 42.32 | 39.08 | 21.62 | 20.02 | 11.63 | 11.05 | 14.31 | 7.50 | 15.99 | 14.64 |
| 97/98 | 47.70 | 43.46 | 21.69 | 19.95 | 13.56 | 12.89 | 15.47 | 8.45 | 16.81 | 15.45 |
| 98/99 | 48.74 | 43.26 | 22.91 | 21.17 | 18.32 | 17.51 | 19.93 | 12.61 | 16.80 | 15.48 |
| 99/00 | 47.39 | 42.93 | 22.94 | 21.08 | 17.93 | 17.07 | 22.89 | 15.07 | 15.45 | 14.14 |
| 00/01 | 49.20 | 44.63 | 24.73 | 22.74 | 18.34 | 17.30 | 26.70 | 18.90 | 18.55 | 16.73 |
| 01/02 | 50.87 | 46.26 | 26.96 | 24.69 | 22.01 | 20.86 | 28.31 | 20.25 | 19.89 | 17.82 |
| 02/03 | 47.52 | 43.95 | 29.65 | 27.17 | 24.80 | 23.53 | 35.29 | 26.54 | 18.11 | 16.48 |
| 03/04 | 44.60 | 41.63 | 32.04 | 29.32 | 26.41 | 25.02 | 34.38 | 25.44 | 15.45 | 14.08 |
| 04/05 | 51.40 | 46.16 | 32.10 | 29.25 | 28.75 | 27.31 | 40.21 | 30.36 | 15.62 | 14.22 |
| 05/06 | 52.41 | 47.32 | 30.65 | 28.05 | 33.34 | 31.89 | 44.54 | 34.50 | 14.99 | 13.53 |
| 06/07 | 52.97 | 48.44 | 30.37 | 27.90 | 36.57 | 35.00 | 47.85 | 37.50 | 15.33 | 13.90 |

*Source*: Foreign Agricultural Service/USDA (FAS/USDA, 2007a).

Through the crushing process, soyoil and soymeal are separated. Soyoil is generally used for human consumption, while soymeal is used for animal feed, especially for the poultry, swine, and dairy industries. In most countries, for every metric ton of soybeans crushed, meal and oil yields are approximately 79 and 17 percent, respectively (Piggott and Wohlgenant, 2002). Therefore, as it can be seen in Table 4, the United States is historically the leading producer of meal and oil in the world, followed by China, Argentina, and Brazil. However, with respect to soybean joint products exports in the 2005/06 MY, the United States is the third largest exporter behind Argentina and Brazil, which are the first and second, respectively (FAS/USDA, 2007a).

**Soybeans in Brazil**

Located in South America, Brazil is the fifth largest country in the world, after Russia, Canada, China, and the United States, with an area of 8,511,965 square km (approximately 3,286,482 square miles). Figure 1 shows Brazil and its twenty six states plus one federal district (DF).

The GDP growth of Brazil increased from 2.3 percent in 2005 to 2.9 percent in 2006. In the last five years, Brazil has experienced an increase in exports and external accounts, low inflation and decrease in the unemployment rate as well as debt-to-GDP ratio. Supported by exports and foreign investments, the real, Brazil’s currency, has remained at strong levels, allowing the government and businesses to pay off external debts. Table 5 presents selected macroeconomic indicators.

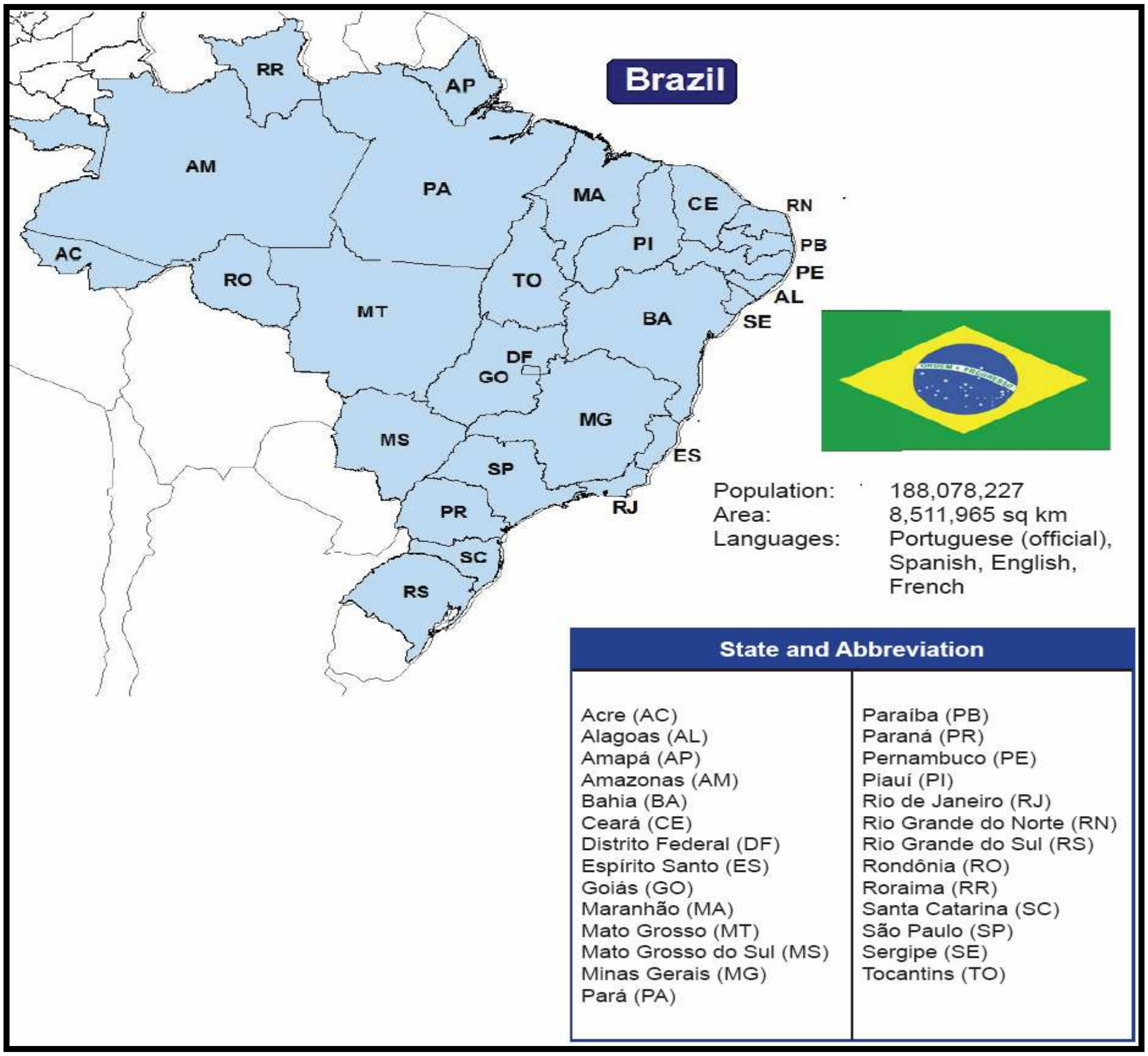


**Figure 1. Map of Brazil and its states**
*Source*: Agricultural Marketing Service/USDA (AMS/USDA) (2007a).

**Table 5. Selected Macroeconomic Indicators for Brazil**

| Indicators | Years | | | | | |
|---|---|---|---|---|---|---|
| | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 |
| GDP Growth (%) | 1.5 | 1.9 | 0.5 | 4.9 | 2.3 | 3.7 |
| Inflation (%) | 7.7 | 12.5 | 9.3 | 7.6 | 5.7 | 3.1 |
| Avg. Exchange Rate (R$/US$) | 2.35 | 2.93 | 3.07 | 2.93 | 2.44 | 2.18 |
| Total Exports (US$ Billion) | 58.2 | 60.4 | 73.1 | 96.5 | 118.3 | 137.5 |
| Total Imports (US$ Billion) | 55.5 | 47.2 | 48.3 | 62.8 | 73.5 | 91.4 |

*Source:* Foreign Agricultural Service/USDA (FAS/USDA, 2007b).

In the last fifteen years, important macroeconomic policies adopted by the Brazilian government had different impacts on the Brazilian economy in general. One policy change was the creation of the Real plan in 1994, which represented a one to one exchange rate of the real to the dollar (R$/US$) and extremely high national interest rates. The impacts of such policy were a rapid increase in imports of industrial goods and inflow of foreign direct investment. One of the objectives of this plan was to control the inflation rate, which in the pre-real era was exorbitant. Later in 1999, a floating exchange rate was adopted, which resulted in the Real devaluation with respect to the dollar. As illustrated in table 5, such devaluation boosted the trade balance, and increased agricultural commodities exports, especially the soybean industry.

As for the agricultural economic indicators of the Brazilian economy, from 1994 to 2006, the agribusiness sector represented nearly 30 percent of the nation’s gross domestic product (GDP) (Figure 2).

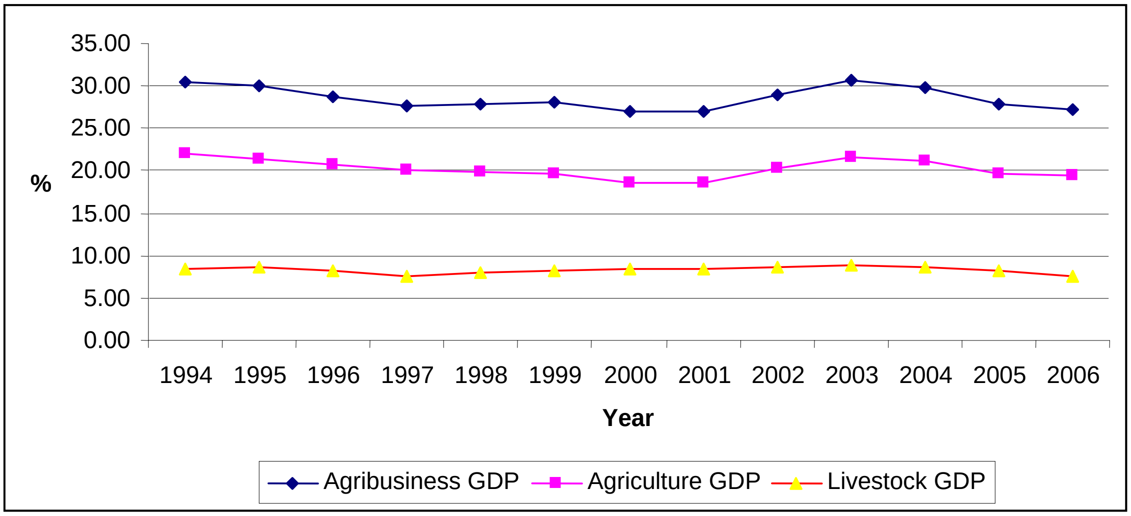


**Figure 2. Agribusiness gross domestic product as a proportion of total gross domestic product, 1994 - 2006**
*Source:* Centro de Estudos Avançados em Economia Aplicada/Universidade de São Paulo (CEPEA, 2007).

Since 1930, Brazil has been focusing on the industrial sector as the main source of economic growth, neglecting the agricultural sector, which was perceived to supply only the domestic market. In 1964, the year that Brazil became a military dictatorship, the support to the industrial sector was stronger than ever. Such support benefited some agricultural commodities, particularly soybeans. Two benefited industrial sectors were the crushing industry and the use of machinery (tractors, harvesters, etc.). Thereafter, the soybean complex in Brazil was introduced in the states of Rio Grande do Sul and Paraná, which are the traditional soybean producing states (Sampaio, 2004).

Beginning of the 1980's, soybean production in Brazil developed in the Central-West, with attention to Mato Grosso. Soybeans were brought to the Central-West region to be planted in the *Cerrado* area. The *Cerrado* area is comprised of a large heterogeneous tropical savanna which occupies more than 2 million hectares, approximately 20 percent of the land area in Brazil. It includes areas from the Amazon complex, most of the Central-West of Brazil, and part of Southeast and Northeast of Brazil. The expansion of soybean production in the *Cerrado* was strongly affected by an increasing domestic and international demand. On the supply side, three factors were decisive: the natural resources of these areas; technological development which made feasible the cultivation of soybeans in formerly incompatible agro-ecosystems; and, although small, investment in transportation infrastructure in these portions of the *Cerrado* (Mueller, 2003).

Figure 3 shows the historical series of soybean production by state and region in Brazil. Between 1976/77 and 2006/07 (forecast), the production of soybeans in the traditional states (RS and PR states) remained important, but the crop has moved deep into the *Cerrado*. In 1976/77, the traditional states were responsible for 84.4 percent of the total production (10.25 MMT); the remaining 15.4 percent (1.895 MMT) was divided almost evenly among the states of São Paulo, Mato Grosso and Goiás. In 1999/00, Rio Grande do Sul and Paraná states remained the two significant producers (third and second largest producers, respectively), but the cultivation of soybean in the savannas of Mato Grosso made it the largest producer in history, with 8.456 MMT. For the forecast of 2006/07, although production has decreased for two years in a row, Mato Grosso is expected to continue as the number one producing state (15.1 MMT) followed by Paraná (12.1 MMT), Rio Grande do Sul (8.2 MMT), Goiás (6.15 MMT), and Mato Grosso do Sul (4.97 MMT).

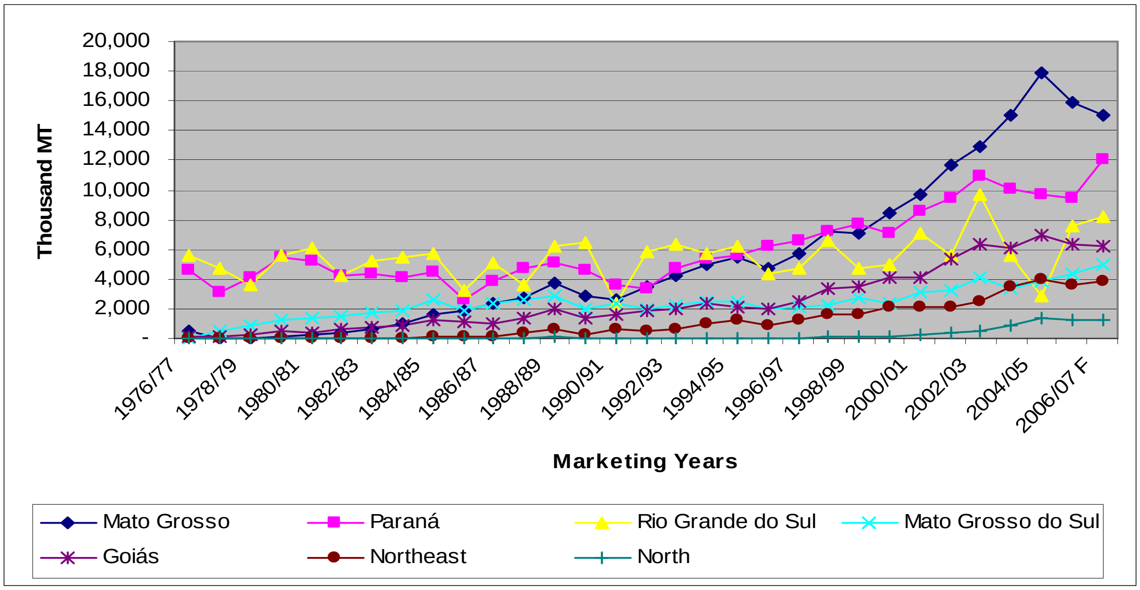


**Figure 3. Historical series of soybean production by state and region, 1976/1977 – 2006/2007**
*Source:* Companhia Nacional de Abastecimento (CONAB/MAPA, 2007a)

Concerning Brazilian soybean export value, according to the CONAB/MAPA (2007b), the soybean complex accounted for $9.31 billion, which represented 6.8 percent of Brazil's total export sales ($137.4 billion) in 2006. Sixty percent ($5.67 billion) was soybean exports, and the remaining 40 percent was divided 26 percent ($2.42 billion) and 14 percent ($1.22 billion) to meal and oil, respectively.

According to the SECEX/MDIC (2007), the EU and China are large importers of Brazilian soybeans and joint products. In 2006, China and the EU imported 10.77 and 9.93 MMT soybeans, respectively, representing 83 percent of Brazil's total soybean exports (24.96 MMT). In the same year, the major importers of meal were the EU with 8.01 MMT, followed by Thailand with 1.21 MMT, together accounting for 75 percent of the Brazilian total exports (12.33 MMT). With respect to Brazilian oil, the EU was the leading importer with 0.87 MMT, followed by Iran (0.69 MMT) and China (0.23 MMT).

These three importers accounted for 74 percent of Brazil's total exports of soyoil (2.41 MMT).

Based on the data from SECEX/MDIC (2007), Brazil's soybean exports are disaggregated to state and region levels as shown in Table 6. From 1989 to 2006, the South region (composed by the states of Paraná, Rio Grande do Sul, and Santa Catarina) was a large exporting region, representing on the average 43 percent of Brazil's total quantity exported. However, with the soybean production expansion in the states in the *Cerrado* region (Mato Grosso, Goiás, and Mato Grosso do Sul), the South region lost ground to these states as its average export share fell to 27 percent in the past three years (2004 to 2006). Furthermore, Mato Grosso became the leading soybean exporting state/region in 2005, passing the South region and accounting for 40 percent of Brazilian exports. For the rest of Brazil (ROB), the states of Minas Gerais, São Paulo, Bahia, Maranhão deserve to be mentioned because of their high exports, 3.56 MMT in 2006 which accounted for 76 percent of ROB's exports in that year.

**Table 6. Soybean Exports by State/Region in Brazil (MMT), 1989 - 2006**

| Year | State/Region | | | | | |
|---|---|---|---|---|---|---|
| | Mato Grosso | Goiás | MS* | South** | Rest of Brazil | Brazil |
| 1989 | 0.47 | 0.46 | 0.36 | 2.60 | 0.73 | 4.62 |
| 1990 | 0.71 | 0.37 | 0.27 | 2.15 | 0.58 | 4.08 |
| 1991 | 0.35 | 0.44 | 0.09 | 0.56 | 0.58 | 2.03 |
| 1992 | 0.67 | 0.22 | 0.16 | 1.84 | 0.85 | 3.74 |
| 1993 | 0.36 | 0.18 | 0.25 | 2.12 | 1.29 | 4.21 |
| 1994 | 0.66 | 0.31 | 0.38 | 2.27 | 1.79 | 5.40 |
| 1995 | 0.36 | 0.10 | 0.30 | 1.55 | 1.19 | 3.49 |
| 1996 | 0.46 | 0.10 | 0.16 | 1.74 | 1.18 | 3.65 |
| 1997 | 1.48 | 0.44 | 0.31 | 4.34 | 1.79 | 8.34 |
| 1998 | 1.37 | 0.42 | 0.07 | 4.87 | 2.57 | 9.29 |
| 1999 | 1.73 | 0.42 | 0.25 | 3.94 | 2.57 | 8.92 |
| 2000 | 2.89 | 0.93 | 0.08 | 4.98 | 2.64 | 11.52 |
| 2001 | 4.50 | 0.79 | 0.45 | 6.82 | 3.11 | 15.68 |
| 2002 | 5.24 | 0.92 | 0.13 | 6.32 | 3.36 | 15.97 |
| 2003 | 4.85 | 2.18 | 0.23 | 8.95 | 3.68 | 19.89 |
| 2004 | 5.04 | 1.84 | 0.35 | 6.79 | 5.23 | 19.25 |
| 2005 | 9.09 | 3.07 | 0.98 | 4.58 | 4.72 | 22.44 |
| 2006 | 9.92 | 2.80 | 1.18 | 6.38 | 4.68 | 24.96 |

* Mato Grosso do Sul **South = Paraná + Santa Catarina + Rio Grande do Sul
*Source:* SECEX/MDIC (2007)

In summary, the consumption/use of soybeans is investigated by breaking down the crushing capacity by state. Although the lack of data for certain years, they were provided by the Associação Brasileira das Indústrias de Óleos Vegetais (ABIOVE) which includes the largest active crushing firms in Brazil.

Table 7 presents the crushing capacity by state/region in Brazil, from 1989 to 2006. The South region and the state of São Paulo represented 82.5 percent of the total Brazilian crushing capacity in 1989. As the production shifted to the Central-West in subsequent years, Brazil's crushing capacity expanded to new regions. In Brazil, soyoil refining plants are located near the final consumers (large cities such as São Paulo), according to Sampaio (2004). On the other hand, the crushing plants are usually distant from the final consumers yet near the producing regions. Therefore, for the Central-West state producers (MT, GO, and MS), the crushing capacity more than tripled, increasing from 11.4 percent in 1989 to 36.1 percent in 2006. In contrast, the crushing capacity in the South region and the state of São Paulo was 52.1 percent in 2006. For the rest of Brazil (ROB), the states of Minas Gerais (6,600 MT/day) and Bahia (5,500 MT/day) represented approximately 71 percent in 2006.

**Table 7. Crushing Capacity by State/Region (Metric Ton/day), 1989 - 2006**

| Year | State/Region | | | | | | |
|---|---|---|---|---|---|---|---|
| | Mato Grosso | Goiás | MS* | South** | São Paulo | Rest of Brazil | Brazil |
| 1989 | 1,200 | 4,500 | 6,100 | 65,678 | 19,403 | 6,270 | 103,151 |
| 1995 | 8,330 | 9,000 | 6,980 | 69,445 | 13,565 | 8,960 | 116,280 |
| 1997 | 8,550 | 9,000 | 6,730 | 70,225 | 13,465 | 10,210 | 118,180 |
| 1998 | 8,770 | 9,660 | 7,480 | 70,910 | 13,780 | 10,310 | 120,910 |
| 2000 | 10,520 | 9,760 | 7,530 | 71,820 | 15,350 | 12,160 | 127,140 |
| 2001 | 10,820 | 8,660 | 7,330 | 54,630 | 14,700 | 11,810 | 107,950 |
| 2002 | 14,500 | 9,060 | 6,630 | 52,850 | 12,950 | 14,570 | 110,560 |
| 2003 | 14,500 | 10,320 | 6,980 | 53,050 | 14,450 | 15,970 | 115,270 |
| 2004 | 20,600 | 16,920 | 7,295 | 55,499 | 14,950 | 16,504 | 131,768 |
| 2005 | 21,000 | 18,150 | 8,295 | 57,349 | 15,600 | 16,704 | 137,098 |
| 2006 | 23,600 | 18,800 | 9,360 | 58,384 | 16,400 | 16,960 | 143,504 |

* Mato Grosso do Sul **South = Paraná + Santa Catarina + Rio Grande do Sul
*Source:* ABIOVE (2007)

**Export Cost Competitiveness of the United States, Brazil, and Argentina**

In this subsection, a succinct comparison of infrastructure indicators is done across the United States, Brazil, and Argentina. The U.S. infrastructure is vastly more developed due to an extensive internal transportation network, centered on the Mississippi river waterway. Therefore, the United States has the advantage of transporting bulk commodities to international markets much more economically and efficiently than Brazil and Argentina. Moreover, U.S. soybean transportation relies heavily on barges, which are the most economical and efficient mode for transporting bulk commodities. Meanwhile, Brazil and Argentina ship soybeans by truck, which is the most expensive transportation mode.

The highway systems in developed areas of Brazil and Argentina are less efficient than those of the United States, and even worse in remote agricultural areas. Consequently, truck freight rates are more expensive in Brazil and Argentina than in the United States. Table 8 shows that only 5.5 percent of Brazil's highways and 30 percent of Argentina's highways are paved. A survey conducted by the Confederação Nacional do Transporte (CNT) shows that 75 percent of Brazil's paved highways have various unidentified deficiencies. In addition, 70.3 percent of the traffic road signs are inadequate, 40.5 percent of the roads do not have shoulders, and 40.7 percent of the roads lack speed limit signs (AMS/USDA, 2007a).

**Table 8. Infrastructure Indicators for Argentina, Brazil, and the United States**

| Item | Unit | Argentina | Brazil | | U.S. |
|---|---|---|---|---|---|
| ***Infrastructure*** [1] | | | | | |
| Total highways | $10^3$ km[2] | 229.14 | 1,724 | | 6,407 |
| Paved highways | $10^3$ km | 68.8 | 94.8 | | 4,164 |
| Total rail track | $10^3$ km | 67.8 | 58.2 | | 227 |
| Navigable waterways | $10^3$ km | 11 | 50 | | 41 |
| | | | South[3] | MT | |
| ***Avg. distance to export point*** | Km | 300 | 300 | 2,000 | 1,400 |
| ***Avg. cost*** [4] | | | | | |
| Barge | $/mt/$10^3$ km | 10 | 8 | 13 | 5 |
| Rail | $/mt/$10^3$ km | 50 | 25 | 30 | 25 |
| Truck | $/mt/$10^3$ km | 60 | 39 | 50 | 45 |
| ***Avg. share of exported soybean by mode*** [5] | | | | | |
| Barge | Percent | 2 | 7 | | 61 |
| Rail | Percent | 16 | 36 | | 23 |
| Truck | Percent | 82 | 57 | | 16 |

[1]CIA Factbook. [2]1000 kms. [3]Rio Grande do Sul (RS) and Paraná (PR). [4]Schnepf et al (2001). [5]ANUT (2004).
*Source*: CIA (CIA, 2007), Schnepf et al. (2001), ANUT (2004).

Regarding railroads, not only do Brazil and Argentina have less rail line availability compared to the United States (Table 8), the railways were built with multiple gauges thereby requiring costly transhipment stops when transporting across different-gauged tracks (Schnepf et al., 2001). Also, according to the Associação Nacional dos Usuários de Transporte de Carga (ANUT, 2004), most of the Brazilian railroads lack sufficient locomotives and railcars to keep up with transportation demand. The estimates are for a growth in demand and a shortage in supply for railroad transportation over the next five years.

To compare the internal transportation systems among the United States, Brazil, and Argentina, an export cost competitiveness analysis is performed. This analysis has been done previously by Schnepf et al (2001) and Flaskerud (2003). It examines the components and distribution of farm-level production costs, the costs of internal marketing and transportation, and shipping costs to a common export destination (Schnepf et al, 2001). Cost data for each country were available for 2003/04, the most recent year that detailed comparisons were possible.

Favorable natural resources, climatic conditions, and large underutilized land areas provide Brazil and Argentina with opportunities to be naturally low-cost producers of soybeans, and hence powerful competitors in the world market. Table 9 illustrates that total per-bushel soybean production costs in Brazil's Mato Grosso ($3.87/bushel) and Argentina ($4.22/bushel) were 27 and 21 percent lower than the United States ($5.11/bushel). Production costs are 24 percent lower in the state of Paraná. Likewise, total per-acre soybean production costs were highest in the United States ($244.84), about $78 more than in Brazil and $34 higher than in Argentina.

The higher production costs in the United States can be attributed to high fixed costs, especially the expensive land costs faced by producers. Compared to Brazil, where estimated land costs per acre are only $15.46 and $25.91 for Mato Grosso and Paraná, respectively, U.S. costs are much higher. One of the reasons for such low land costs in Brazil's Mato Grosso is the abundant availability of *Cerrado* soils to be converted into agricultural land. However, based only on variable costs, the United States has an advantage compared to Brazil. According to Schnepf et al, this might be explained by high fertilizer and chemicals costs in Mato Grosso (higher prices rather than greater intensity of application) and great fertilizer and labor costs in Paraná (small scale and labor-intensive practices).

**Table 9. Soybean Production Costs and Export Cost Competitiveness: United States, Brazil, and Argentina, 2003/04.**

| Cost Item | U.S. Heartland[1] | Brazil[2] MT | Brazil[2] PR | Argentina |
|---|---|---|---|---|
| **Variable costs:** | *US $ per acre* | | | |
| Seed | 28.67 | 12.79 | 10.54 | 18.57 |
| Fertilizers | 7.73 | 47.00 | 22.22 | 6.26 |
| Chemicals | 17.10 | 35.47 | 38.61 | 17.56 |
| Machine Operation Repair | 22.13 | 18.02 | 22.82 | 21.36 |
| Interest on Capital | 1.00 | 7.38 | 5.32 | 9.87 |
| Hired Labor | 1.26 | 1.46 | 5.59 | 6.08 |
| Harvest & Miscellaneous | n/a | 7.09 | 10.24 | 12.49 |
| **Total variable costs** | **77.88** | **129.21** | **115.35** | **92.21** |
| **Fixed Costs:** | *US $ per acre* | | | |
| Depreciation of machinery | 51.36 | 16.83 | 18.96 | 22.14 |
| Land costs (rental rate) | 97.45 | 15.46 | 25.91 | 72.78 |
| Taxes, insurance & overhead | 18.15 | 5.35 | 6.54 | 23.98 |
| **Total fixed Costs** | **166.96** | **37.63** | **51.40** | **118.90** |
| **Total production costs** | **244.84** | **166.84** | **166.75** | **211.11** |
| **Costs per bushel:** | *US$ per bushel (% of U.S. cost)* | | | |
| Yield (bushels/acre) | 46.00 | 43.07 | 41.38 | 50.00 |
| Variable costs per bushel | 1.69 | 3.00 | 2.79 | 1.84 |
| Fixed costs per bushel | 3.63 | 0.87 | 1.24 | 2.38 |
| **Total costs per bushel** | **5.32** | **3.87 (73)** | **4.03 (76)** | **4.22 (79)** |
| Internal transp. (US$/bu.) | 0.48 | 1.80 | 0.81 | 0.72 |
| **Cost at border** | **5.81** | **5.67 (98)** | **4.84 (83)** | **4.94 (85)** |
| Freight costs to Rotterdam | 0.39 | 1.25 | 1.25 | 1.03 |
| **Landed cost at Rotterdam** | **6.20** | **6.92 (112)** | **6.09 (98)** | **5.97 (96)** |

[1] Illinois, Indiana, Iowa, Michigan, Minnesota, Ohio, Wisconsin.[2] Mato Grosso (MT) and Paraná (PR).
*Source*: Costa et al. (2007).

Nevertheless, internal transportation costs for soybeans narrow the gap between the South American countries and the United States. Table 9 indicates that internal marketing, such as storage costs, and transportation costs averaged two to three times higher in Brazil and Argentina than in the United States, reducing farmgate prices. These costs averaged $1.80/bushel for Mato Grosso, $0.81/bushel for Paraná, and $0.72/bushel for Argentina. In the United States, these costs averaged $0.48/bushel.

With respect to shipping charges to Rotterdam, Table 9 points out that the United States has a considerable advantage over both Brazil and Argentina. In the cases of Paraná state and Argentina, this further narrows the export cost differentials when the combined production and transportation costs are compared at the port of entry. For Mato Grosso, it is even worse; it goes from the most efficient producer to the most expensive supplier at the importing port. According to Schnepf et al (2001), the difference between the United States and the South American countries in terms of the FOB (free on board) export price and CIF (cost, insurance and freight price) spreads is most likely due to distance and higher insurance and demurrage costs for ships originating from these countries.

In Table 9 estimations, the results correspond to other studies, especially transportation costs values. A Brazil soybean transportation report done by AMS/USDA (2007a) shows almost identical transportation costs indicators. According to the report, from the North of Mato Grosso to Hamburg, Germany, transportation cost (truck and ocean charges) accounts for 43 percent ($123.81/MT) of the total landed cost ($288.70/MT). Of this 43 percent, 27 percent ($78.05/MT) is farm to export port transportation cost and the remaining 16 percent ($45.76/MT) is ocean shipping charges. Table 9 shows that, from Mato Grosso to Rotterdam (freight costs to Hamburg or

Rotterdam might not be significantly different), the same transportation cost represents 44.1 percent. For Paraná, this proportion is 23.77 percent from the AMS report and 33.8 percent based on the estimations in Table 9.

Schnepf et al (2001) found that the internal transportation costs and freight costs from Brazil to Rotterdam accounted 33 percent ($1.91/bushel) of total landed cost ($5.80/bushel) for the 1998/99 MYs. The main difference between analysis conducted by Schnepf et al (2001) and Table 9 estimations is a lower ocean freight cost for 1998/99 MYs (exporting port in Brazil to Rotterdam), which was $0.57/bushel (10 percent) compared to $1.25/bushel for 2003/04 MYs. On the other hand, Table 9 estimates for internal transportation costs matches with estimation from Schnepf et al (2001) of 23 percent ($1.34/bushel).

In another soybean landed costs analysis, Flaskerud (2003) concluded that for Mato Grosso, total freight costs (farm to exporting port and ocean) are higher than that for Iowa and North Dakota and it represented almost 30 percent of the total cost at Rotterdam.

To summarize, the underlying cost structures for producing, transporting, and marketing soybeans from Brazil's two principal regions and Argentina allow them to ship soybeans to Rotterdam at prices slightly below the United States, except for Mato Grosso. These cost advantages partially explain the fast expansion of soybean production and exports by Brazil and Argentina during the past two decades.

## Objectives

An intertemporal spatial equilibrium model was developed to analyze the economic impacts of transportation infrastructure improvement in Brazil on the world soybean market. Specifically, the objectives of the study are as follows:

i. Enhance the understanding of Brazil's recent and expected improvements in its transportation and marketing network.
ii. Apply the developed mathematical transportation model to estimate changes in producer revenues on Brazil and the rest of the world.
iii. Evaluate the impacts of improvements in Brazil's transportation infrastructure on the soybean sector of the United States, Brazil, and Argentina regarding export levels, producer revenues, and prices.

## Procedure

The spatial intertemporal model developed in this study is a quadratic programming model that features regional excess soybean supply and excess soybean demand relationships. By solving spatial models, solutions are generated which reflect interregional commodity flows and prices that result from maximizing producer and consumer surplus minus all costs related to handling the commodity, including transportation (Samuelson, 1952; Takayama and Judge, 1971).

This study focused on improvements in infrastructure in Brazil and how they may affect the world soybean market. Recent transportation infrastructure projects proposed by the Brazilian government were investigated. A base model was developed including transportation costs *ex ante* improvement and another model was also developed containing *ex post*, the improved transportation network. Brazil was represented by 18 excess supply regions and eight excess demand region. Other excess soybean supply regions were the United States, Argentina, and the rest of South America (Bolivia, Paraguay, and Uruguay), Canada, and India. China, the European Union (EU-25), Southeast Asia, Mexico, and the Rest of the World (ROW) were excess soybean demand regions.

Annual production data of Brazil by state, counties, and cities from 1990 to 2005 were collected from the Instituto Brasileiro de Geografia e Estatística (IBGE/MPOG, 2007). To investigate the excess demand regions, consumption by state/region was represented by the crushing capacity shown in Table 7. With respect to truck, railroad, and waterway freight rates, the Sistema de Informações de Fretes (SIFRECA, 2007) provided data for several transportation routes in Brazil. Freight rates for the new improved routes were estimated econometrically using the data supplied by SIFRECA (2007).

Chapter II has in depth analysis on Brazilian domestic soybean transportation and possible improvements in transportation infrastructure. Chapter III offers a brief literature review on relevant studies previously realized to analyze transportation changes and how they affect markets in general. Also, it presents relevant spatial intertemporal equilibrium methodology incorporating price-endogenous analysis. Moreover, estimation of parameters to develop the model (such as excess soybean supply and demand elasticities, production, consumption, and trade projections, and freight rate equations) is outlined. Chapter IV presents the validation procedure to evaluate the model with respect to its prediction power. Chapter V relates the simulation results of improvements in transportation infrastructure in Brazil and the impact on the world soybean market. Chapter VI presents a summary and conclusions.

# CHAPTER II

# BRAZIL SOYBEAN PRODUCING STATES/SUB-REGIONS AND THEIR TRANSPORTATION NETWORK

This chapter provides background on production and transportation in selected soybean producing states/sub-regions in Brazil that are significantly affected by the lack of adequate transportation infrastructure. It also provides information of recent efforts on the transportation infrastructure improvements that may enhance Brazil's export competitiveness in the world soybean market.

## The State of Mato Grosso and Its Sub-regions

The state of Mato Grosso is the third largest state in Brazil with approximately 903,357 square kms (564,599 square miles). As it was described in the previous chapter, Mato Grosso is the leading soybean producing and exporting state in Brazil (Figure 3 and Table 6, respectively). This state is considered as the most inefficient regarding internal soybean transportation (Table 9). Soybean production in Mato Grosso is well distributed throughout the state. Improvements in transportation infrastructure will have different impacts in different sub-regions of the state. Therefore, dividing the state into sub-regions is appropriate to analyze the impacts of future improvements.

The sub-regions are (in parentheses, main city of the sub-region): West (Campo Novo dos Parecis), North (Sorriso), Northeast (Nova Xavantina), and Southeast (Rondonópolis). These sub-regions were divided based on the study conducted by the Empresa Brasileira de Planejamento de Transportes (GEIPOT/MT, 2001), which investigated the soybean transportation from farm to importing port for several states/sub-regions in Brazil for the years of 2000 and 2015. In addition, new routes were proposed for each state/sub-region for the year of 2015 and estimates were made on how much the transportation costs would be reduced by utilizing these new routes.

*The West of Mato Grosso*

The West sub-region has two main producing areas, Sapezal and Campo Novo dos Parecis. They were the second and third largest producing regions within Mato Grosso, respectively. In 2005, the farmers located in both areas harvested 2.24 MMT soybeans which accounted for 30.9 percent (5.49 MMT) of total soybean production in Mato Grosso in 2005 (IBGE/MPOG, 2007). Figure 4 shows the geographic location of Campo Novo dos Parecis[2] (circle in gray) and the current soybean transportation routes for the West sub-region (arrows in gray).

According to the GEIPOT/MT (2001), there are currently several routes where soybeans are transported from farms in the sub-region to exporting ports. Only four routes are considered to be the most important ones for the West sub-region. The most important one is through the Madeira-Amazon waterway, which connects soybean production in the West sub-region to an Amazon River elevator via the Madeira river. A joint venture involving the Maggi Group and the state of Amazonas invested in a river elevator at Porto Velho in the state of Rondônia (Madeira river), a barge-to-ocean vessel transfer facility at Itacoatiara, a port on the Amazon river in the state of Amazonas, and a

[2] Campo Novo dos Parecis will represent the sub-region in accordance to the study done by GEIPOT/MT (2001).

fleet of barges and towboats that operate between Porto Velho and Itacoatiara (Fuller et al, 2001). Soybeans are also shipped by truck through the BR-364 highway to Porto Velho (Figure 4, red line), a distance of 1,046 kms (653 miles), where they are loaded onto barges and moved down the Madeira river for approximately 1,100 kms (687 miles) to a floating ship-loading facility at Itacoatiara port (Figure 4, blue line). At this facility, soybeans are transferred from barges to vessels that travel about 1,000 kms (625 miles) down the Amazon river to the ocean.

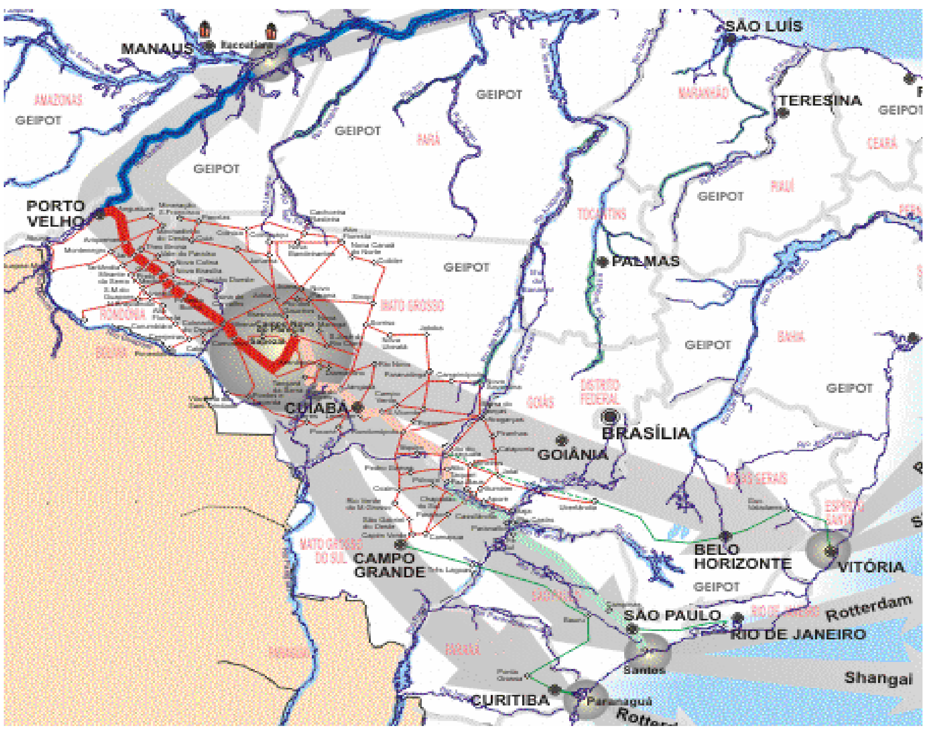


**Figure 4. Current soybean transportation routes for the West of Mato Grosso**
*Source:* Empresa Brasileira de Planejamento de Transportes (GEIPOT/MT, 2001)

Another important route, however, not as efficient as the previous one, is through the Ferronorte railroad. This railroad currently connects the southeast border region of

Mato Grosso (city of Alto Taquari) to the port at Santos via another railroad; Ferroban (Figure 4, light green line). Therefore, soybeans have to be shipped by truck through the BR-364 highway from Campo Novo dos Parecis, approximately 868 kms (542 miles), to Alto Taquari (Figure 4, pink line).

Even though these two previously mentioned routes are important concerning the usage of different transportation modes vis-à-vis reduction in transportation costs, most of the soybeans from the West sub-region are shipped directly by truck via the BR-364 highway to the exporting ports of Santos and Paranaguá. The distance between Campo Novo dos Parecis and Santos and Paranaguá are 2,037 (1,273) and 2,176 (1,360) kms (miles), respectively.

For soybean transportation flows, CONAB/MAPA (2007c) estimated that 1.24 MMT were transported by truck from the major area[3] to the exporting ports of Santos and Paranaguá in 2005. In the same year, 1.14 MMT of soybeans were shipped from the major producers to the Itacoatiara river port through the Madeira-Amazon waterway. The remainder of the production (0.38 MMT) was transported to Cuiabá and Rondonópolis by truck to be crushed.

According to the GEIPOT/MT (2001) study, with respect to transportation infrastructure improvements for the West sub-region, the construction of the Tapajós-Teles Pires waterway is expected to improve the soybean transportation more than the other projects (e.g. expansion of the Ferronorte railroad to Rondonópolis, Mato Grosso).

[3] The cities of Sapezal, Campo Novo dos Parecis, and Campos de Júlio represented 50 percent of the West sub-region production.

This waterway would link soybean production in the West sub-region to the Santarém port located on the Amazon river. First, the soybeans would travel nearly 600 kms (375 miles) by truck from Campo Novo dos Parecis to Cachoeira Rasteira, on the border of Mato Grosso and Pará states, where soybeans would be loaded into barges (Figure 5, red line). These would travel about 1,043 kms (652 miles) through Teles Pires and Tapajós rivers to the exporting port of Santarém (Figure 5, blue line). At this exporting port, soybeans are transferred from barges to vessels that travel about 558 kms (349 miles) down the Amazon river to the ocean.

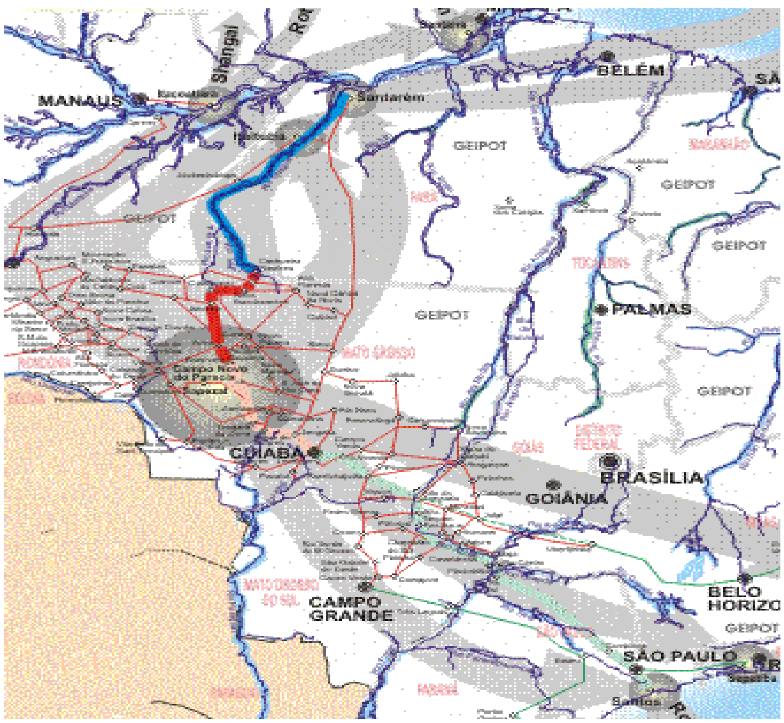


**Figure 5. Improved soybean transportation routes for the West Sub-region of Mato Grosso**
*Source:* Empresa Brasileira de Planejamento de Transportes (GEIPOT/MT, 2001)

According to the FAS/USDA (2005), it is estimated that $200 million will be invested to construct the Tapajós – Teles Pires waterway over the next four years through public-private partnerships (PPPs). This amount represents a large part of the total construction cost, which is around $300 million, according to ANUT (2004). The PPPs have been a frequent topic among representatives of Brazilian economic sectors. It is expected that PPPs will achieve at least part of the improvement of soybean transportation, which could not be done by the government. The Brazilian government is working on PPPs to improve infrastructure and this waterway is part of the government plans. While significant private funds are likely to be committed to PPPs, the government has been cautious in providing the details on how such projects will be executed. According to the Departamento Nacional de Infra-Estrutura de Transportes (DNIT/MT, 2007b), in the newly released Brazilian government Programa de Aceleração do Crescimento (PAC) – 2007/2010[4], the Tapajos – Teles waterway will not receive government investments for this period.

In summary, for the West sub-region, the current transportation routes are through waterways, railroads, and roads. The implementation of the Tapajós – Teles Pires waterway is extremely important vis-à-vis reduction in transportation costs for the local soybean farmers. If this waterway is constructed, using the data from Sistema de Informações de Fretes (SIFRECA, 2007), estimates are that transportation costs would

---

[4] Such program is a Multiyear plan proposed by the current re-elected government to support Brazil's economic development for at least the next four years. The government along with private sector via PPPs is expected to invest R$ 503.9 billion ($240 billion) in infrastructure, which R$ 58.2 billion ($27.7 billion) will be allocated for transportation infrastructure.

be around $31.65/MT, which represents a reduction of $11.65/MT when compared to the less costly one (Madeira-Amazon waterway).

*The North of Mato Grosso*

The North of Mato Grosso is the leading soybean producing sub-region with 6.42 MMT production in 2005, which accounted for 36 percent (6.42 MMT) of the total state's production. Among the producing areas in this region, Sorriso and Nova Mutum are the main contributors to the sub-region with the production of 2.87 MMT for 2005. For the same year, Sorriso was the largest soybean producing area not only in Mato Grosso, but also in Brazil (1.8 MMT) (IBGE/MPOG, 2007). Figure 6 illustrates the geographic location of Sorriso (circle in gray) and the current soybean transportation routes for the North sub-region (arrows in gray).

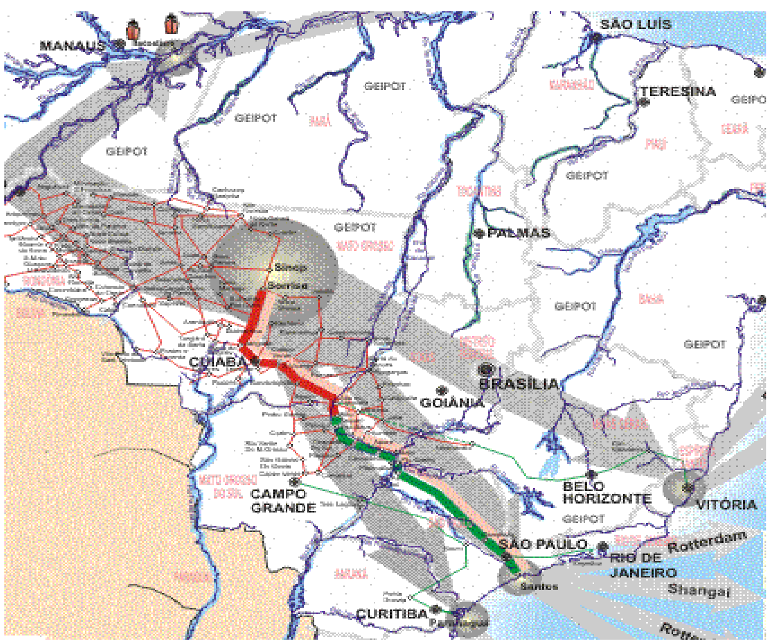


**Figure 6. Current soybean transportation routes for the North of Mato Grosso**
*Source:* Empresa Brasileira de Planejamento de Transportes (GEIPOT/MT, 2001)

The soybean transportation routes for the North of Mato Grosso are similar to the West sub-region. According to GEIPOT/MT (2001), the Madeira-Amazon waterway and the Ferronorte railroad both play a major role in transporting soybeans for local farmers. The only difference between this sub-region and the West sub-region is the distance that trucks have to travel to reach a different unloading facility. From Sorriso to the river port of Porto Velho, trucks travel 1,414 kms (883 miles). As for the railroad, trucks travel approximately 819 kms (512 miles) from Sorriso to the train terminal located in Alto Taquari (Figure 6, red line). Soybeans are then loaded in railcars and travel 1,262 kms (788 miles) to the Santos port at the Atlantic ocean (Figure 6, green line).

With respect to soybean flows, roads are currently the main transportation mode. Most of the local soybean production regularly travels 2,029 kms (1,268 miles) and 2,179 kms (1,361 miles) to Santos and Paranaguá ports, respectively. Trucks depart Sorriso through highway BR-163 which intersects with the highway BR-364, in the state capital of Cuiabá. From Cuiabá to the export destination, trucks have to travel in two-lane roads, and most of which are in very poor condition and heavily congested.

Based on the study done by GEIPOT/MT (2001), the two most important projected transportation routes for the North of Mato Grosso are: (i) the Tapajós – Teles Pires waterway construction; and (ii) the completion of the BR-163 highway connecting Sorriso to Santarém port.

Similar to the West sub-region, the Tapajós – Teles Pires waterway will also facilitate the soybean transportation from farms to the exporting ports. As it can be seen in Figure 7, trucks loaded with soybeans would travel 713 kms (445 miles) from Sorriso to Cahoeira Rasteira (Figure 7, red line). Then, soybeans would be loaded onto barges which would travel north nearly 1,043 kms (651 miles) to the Santarém port (Figure 7, blue line).

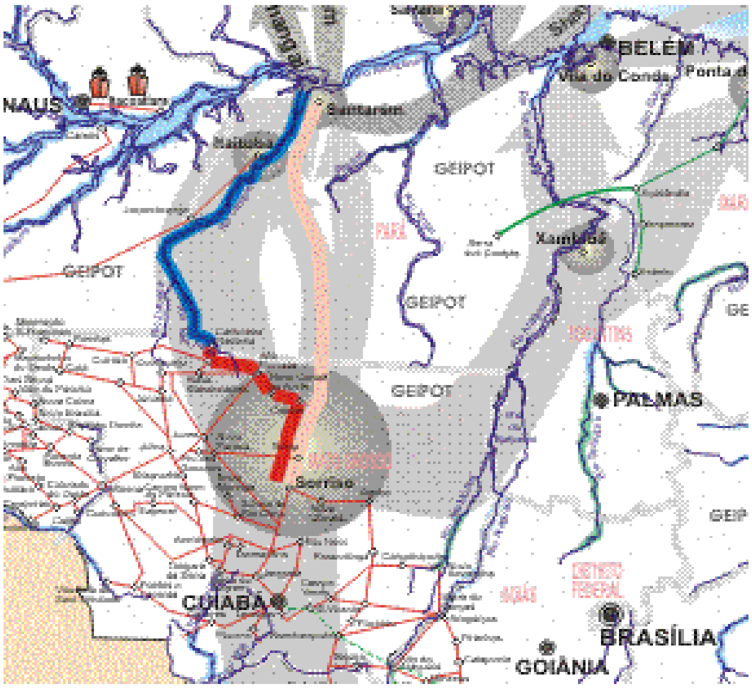


**Figure 7. Improved soybean transportation routes for the North Sub-region of Mato Grosso**
*Source:* Empresa Brasileira de Planejamento de Transportes (GEIPOT/MT, 2001)

Upon the completion of highway BR-163, Sorriso will be linked to the Amazon river port of Santarém (Figure 7, pink line). Currently, this highway can be utilized for only eight months out of the year. For the remaining months, the road is impassable due to heavy rainfall. Also, most of this road is unpaved, especially the portion close to the final destination, the port of Santarém. This north-south route will be extended from Cuiabá, the capital of Mato Grosso, to central Mato Grosso and the state of Pará. It is estimated that this highway will reduce truck traveling distance to port by over 500 kms (312 miles) compared to current exporting ports of Santos and Paranaguá.

Similar to the Tapajós – Teles Pires waterway, highway BR-163 current plans are around $260 million in investments through the PPPs program over the next five years (FAS/USDA). According to the DNIT/MT (2007b), the PAC – 2007/10 will dedicate $714 million to complete the construction of highway BR-163.

For the North sub-region, trucks still are the major transportation method. The implementation of the Tapajós – Teles Pires waterway is extremely important vis-à-vis reduction in transportation costs for the local soybean farmers. In case of no investment in the mentioned waterway, the completion of highway BR-163 is a potential transportation costs savings route for local farmers. Bu using the data from SIFRECA (2007), the estimated cost savings for this route relative to direct truck shipments to Atlantic Coast ports is $20.00/MT.

*The Northeast of Mato Grosso*

For the Northeast of Mato Grosso, the city of Nova Xavantina is the representative origin for transportation routes (GEIPOT/MT, 2001). The soybean production of Nova Xavantina was 0.09 MMT in 2005. The main producing areas for this sub-region are Querência and Canarana with the production of 0.33 and 0.31 MMT, respectively. Further, this sub-region ranks the last in state production, representing only 9.6 percent (1.7 MMT) of total production in Mato Grosso for 2005 (IBGE/MPOG, 2007). Figure 8 illustrates the current soybean transportation routes from the Northeast of Mato Grosso (gray arrows) and Nova Xavantina (gray circle).

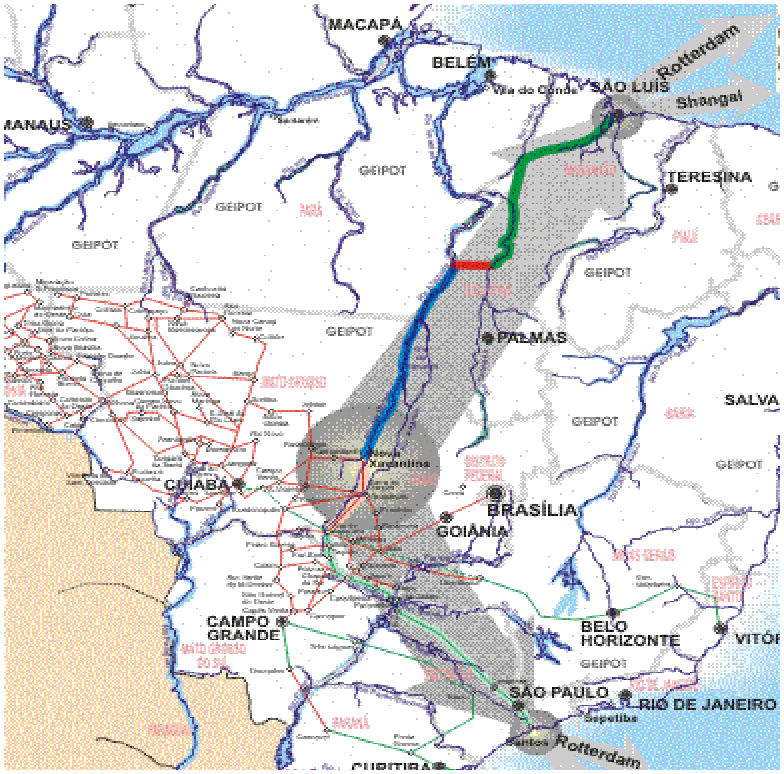


**Figure 8. Current soybean transportation routes for the Northeast of Mato Grosso**
*Source:* Empresa Brasileira de Planejamento de Transportes (GEIPOT/MT, 2001)

Even though soybean production for the Northeast of Mato Grosso is appreciably less than to that of other sub-regions, there still is an abundance of arable land in this sub-region. Soybean producing area might expand even further to north of Mato Grosso bordering Pará and Tocantins states. Improved transportation infrastructure would likely facilitate soybean expansion in this area.

The Mortes – Araguaia waterway is an important on-going transportation project and connects the Northeast sub-region to the Atlantic port of Itaqui at São Luis, Maranhão. However, environmental concerns arising from construction of necessary locks has prevented development of this route. This waterway is formed by two rivers, Mortes and Araguaia. According to GEIPOT/MT (2001), initially soybeans are loaded into barges at the Nova Xavantina river port. Then, the barges travel 1,302 kms (813 miles) along the Araguaia river to Xambioá city river port in the state of Tocantins (Figure 8, blue line). At Xambioá, the soybeans are transferred to trucks from where they travel nearly 161 kms (100 miles) to Estreito, Maranhão (Figure 8, red line). From Estreito to the port of Itaqui at Sao Luis, Maranhão, the soybeans are loaded into railcars operated by the Norte-Sul railroad which interlines with the Carajás (EFC) railroad for final transport to the exporting port (Figure 8, green line), a total rail trip of 717 kms (448 miles).

Besides the waterway-road-railroad route to the Itaqui port and roads to Santos and Paranaguá ports, another soybean transportation route that has been utilized by farmers in the Northeast of Mato Grosso is the Ferronorte railroad. Trucks transport soybeans from Nova Xavantina to Alto Taquari (approximately 450 kms – 281 miles) where Ferronorte train terminal is located. From Alto Taquari, trains transport soybeans to the exporting port of Santos.

As for soybeans flows, similar to previously analyzed sub-regions, trucks are the main transportation used for local soybean farmers and railroads are few and a secondary option. As mentioned earlier, the Mortes – Araguaia waterway is an on-going project and requires large investments throughout the rivers as well as solution to crucial environmental issues[5]. According to ANUT (2004), the required investments for proper

[5] The waterway is currently not being used and is under litigation due to environmental issues.

operation are around $50 million. The Ferronorte railroad is also used to transport soybeans to the port of Santos.

Another potential transportation infrastructure improvement described by GEIPOT/MT (2001) is the expansion of the Mortes – Araguaia waterway through the Tocantins river. The Araguaia river and Tocantins river meet before they reach the Tucuruí dam. The original project of the Mortes – Araguaia waterway was to make the river navigable to the north Brazil port at Belém, Pará, but environmental concerns related to construction of locks have prevented the completion of this route. As Figure 9 shows, the waterway would link Nova Xavantina river port to the Belém exporting port, Pará (Figure 9, blue line). The total barge trip is 1,931 kms (1206 miles).

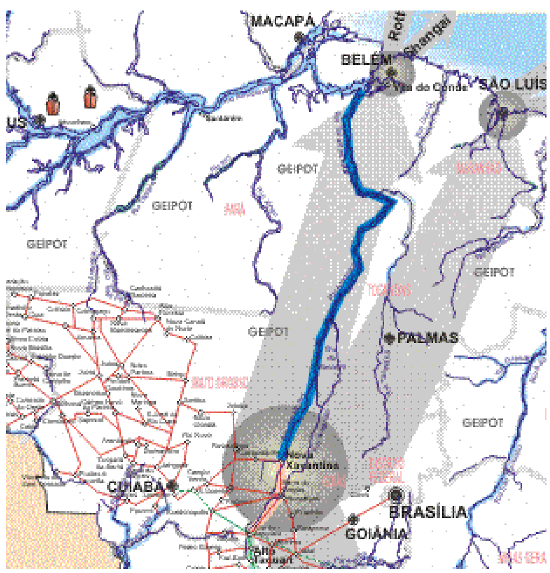


**Figure 9. Improved soybean transportation routes for the Northeast Sub-region of Mato Grosso**
*Source:* Empresa Brasileira de Planejamento de Transportes (GEIPOT/MT, 2001)

To make the waterway accessible to the Belém port, river transposition[6] and the Tucuruí lock construction are required to avoid a waterfall of 70 meters. The DNIT/MT (2007b) indicated that $260 million will be invested for the improvement of Mortes – Araguaia (Tocantins) waterway through the Brazilian government PAC for the years from 2007 to 2010.

In summary, the development of the Mortes – Araguaia (Tocantins) waterway is expected to reduce transportation costs for the Northeast of Mato Grosso considerably. By using the data supplied from SIFRECA (2007), the transportation cost is estimated at $25.85/MT, which represents a reduction of approximately $11/MT compared to shipping by truck. If the environmental concerns are resolved, the construction will facilitate soybean acreage expansion, not only in the state of Mato Grosso, but also in bordering states.

*The Southeast of Mato Grosso*

In 2005, the largest soybean producing areas in the Southeast of Mato Grosso were Primavera do Leste (0.68 MMT) and Itiquira (0.46 MMT). These two areas represented 27.5 percent of the total Southeast sub-region production (4.14 MMT). These 4.14 MMT accounted for 23 percent of total state production (IBGE/MPOG, 2007). Following the GEIPOT/MT (2001) analysis, the city of Rondonópolis will be the origin for transportation analysis in the Southeast of Mato Grosso. Figure 10 highlights the current soybean transportation routes for the Southeast of Mato Grosso (gray arrows)

[6] The river transposition is referred as *Corredeiras de Santa Isabel*.

and Rondonópolis geographical location (gray circle).

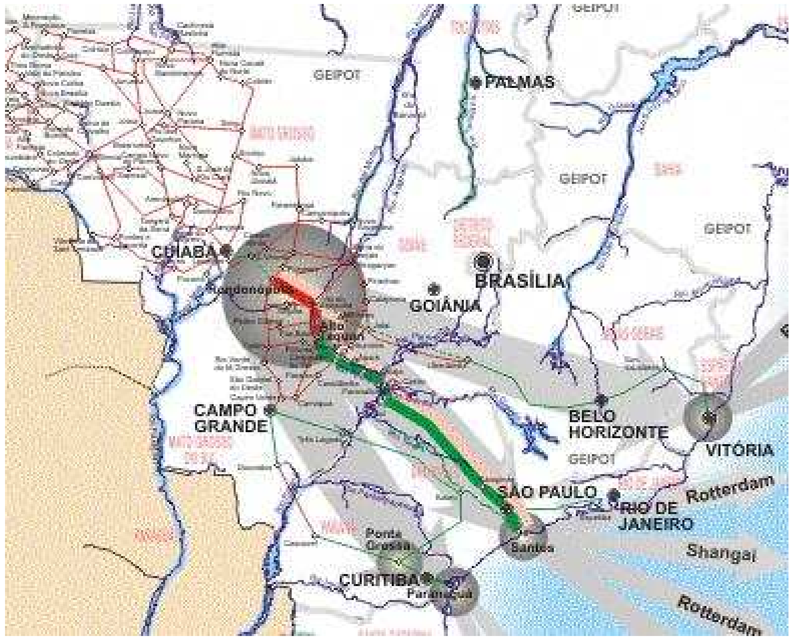


**Figure 10. Current soybean transportation routes for the Southeast of Mato Grosso**
*Source:* Empresa Brasileira de Planejamento de Transportes (GEIPOT/MT, 2001)

GEIPOT/MT (2001) indicated that the soybean transportation routes frequently used by farmers through the Southeast of Mato Grosso are: (i) trucks travel approximately 267 kms (166 miles) from Rondonópolis to Alto Taquari (Figure 10, red line), and then the soybeans are loaded in railcars and transported to the final destination, the Santos port (Figure 10, green line); and (ii) trucks depart Rondonópolis and travel to the export destination, either Santos or Paranaguá port (Figure 10, pink line). For the second route, the total road trip is equivalent to 1,436 kms (897 miles) and 1,586 kms (991 miles).

In Mato Grosso, the soybean crushing plants are located in the cities of

Rondonópolis and Cuiabá[7], which are both located in the Southeast sub-region. A significant proportion of soybeans locally produced are kept in the sub-region for crushing. However, almost 50 percent of the soybeans produced are exported or are shipped to other states for processing.

According to GEIPOT/MT (2001), the expansion of the Ferronorte railroad to Rondonópolis will be a significant improvement in transporting soybeans to Santos port. Figure 11 below presents the mentioned railroad expansion. At Rondonópolis, railcars would be loaded and travel approximately 1,602 kms (1001 miles) to the port of Santos (green line).

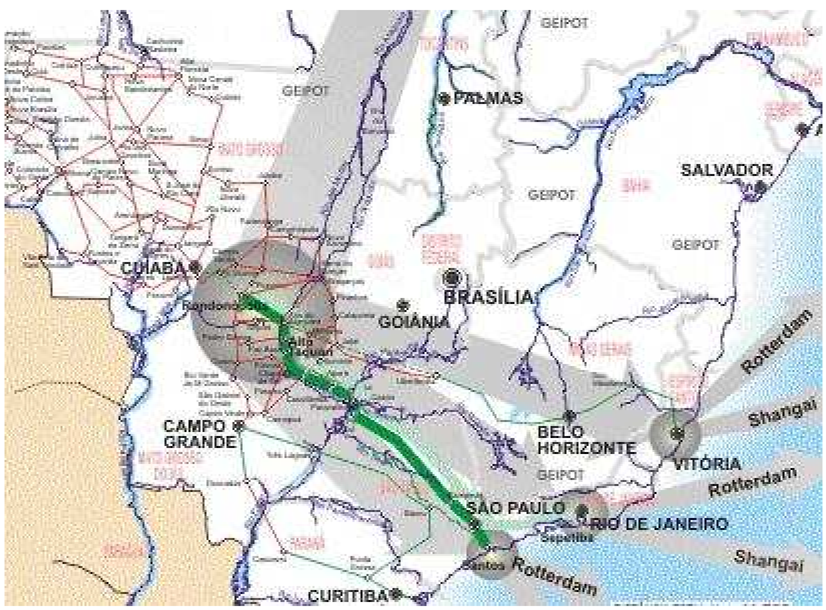


**Figure 11. Improved soybean transportation routes for the Southeast Sub-region of Mato Grosso**
*Source:* Empresa Brasileira de Planejamento de Transportes (GEIPOT/MT, 2001)

---

[7] In 2006, the total crushing capacity for the state of Mato Grosso was 21,400 MT/day (ABIOVE, 2007).

Recently, the largest railroad company in Latin America, the America Latina Logística (ALL) bought the Ferronorte as well as other railroad companies. The future plans of the ALL are to extend Ferronorte rail lines to Rondonópolis, Cuiabá, and eventually to Porto Velho and Santarém river ports. Additionally, ALL intends to connect Alto Araguaia to Uberlândia, Minas Gerais, which will cross other important soybean areas in the states of Goiás and Minas Gerais. To date, the railroad has only been extended to Alto Araguaia, Mato Grosso, which represents 90 kms (56 miles) of rail trip to Alto Taquari. According to DNIT/MT (2007b), the newly released Programa de Aceleração do Crescimento (PAC) 2007/10, has set apart $334 million for the next four years[8] to expand the Ferronorte railroad to Rondonópolis.

In summary, the Ferronorte railroad expansion from Alto Araguaia to Rondonópolis is expected to not only reduce transportation costs, but also to increase soybean shipments to Santos by train. If the Ferronorte is eventually expanded to Cuiabá and Porto Velho and Santarém ports, total transportation cost for this rail trip would be equal to $35/MT, which represents a reduction of only $1.00/MT when compared to other regions and the respective proposed improvements.

## The State of Goiás

The state of Goiás is located in the Central-West of Brazil. It borders the states of Mato Grosso (West), Tocantins (North), Minas Gerais and Bahia (East-South), and Mato

[8] Most of this amount will come through PPPs once it is approved in the Brazilian congress.

Grosso do Sul (South). Also, it is the seventh largest state with 341,289 square kms (213,305 square miles).

The state of Goiás is currently fourth in both soybean production and exports with 6.98 and 2.80 MMT, respectively (Figure 3 and Table 6). The major producing areas are Rio Verde, Jataí, and Mineiros which are located in the south of Goiás. These areas are first, second, and fourth in production within the state, respectively. Altogether they produced 1.64 MMT soybeans in 2005, accounting for a little over 23 percent of the state's production (IBGE/MPOG, 2007). The city of Rio Verde is chosen to represent the state of Goiás regarding transportation infrastructure routes and future improvements.

Figure 12 illustrates the present soybean transportation routes for the state of Goiás. According to GEIPOT/MT (2001), the most important transportation route utilizes three different modes: roads, railroads, and waterways. Trucks depart Rio Verde and travel approximately 206 kms (128 miles) to a Tietê-Paraná waterway terminal located at the city of São Simão, Goiás (Figure 12, red line). At São Simão, barges are loaded with soybeans and travel nearly 759 kms (474 miles) to the city of Anhembi, São Paulo (Figure 12, blue line). Then, soybeans are loaded in railcars and are headed to the Santos port (Figure 12, green line). The total rail trip is equivalent to 351 kms (219 miles).

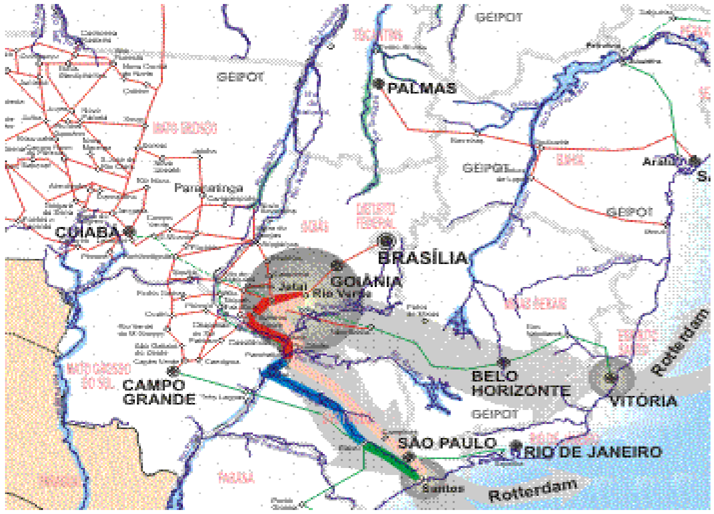


**Figure 12. Current soybean transportation routes for the State of Goiás**
*Source:* Empresa Brasileira de Planejamento de Transportes (GEIPOT/MT, 2001)

An alternative route, also frequently used due to proximity to the port, is from Rio Verde all the way down to the port of Santos. Using this route, trucks travel through highway BR-364 into the state of São Paulo and eventually reach the final destination of Santos port. The total road trip is 959 kms (599 miles) and is represented by the pink line in Figure 12.

The state of Goiás ranks the fourth in crushing capacity in Brazil with 18,800 MT/day for 2006 (Table 6). Therefore, it is expected that a large proportion of soybean production remains in the state to be transformed into soymeal and soyoil. Due to moderate farm to port distance truck transportation is also important for this state compared to other states (such as Mato Grosso)

Transportation infrastructure improvements will benefit the state of Goiás considerably. GEIPOT/MT (2001) suggests that the expansion of the Ferronorte Railroad, connecting Alto Araguaia, Mato Grosso, to Uberlândia, Minas Gerais, will be an attractive soybean transportation route. Figure 13 illustrates how the expansion of the Ferronorte railroad would connect soybeans from Goiás to the port of Santos. At Rio Verde, soybeans would be loaded into railcars and transported to Uberlândia, Minas Gerais, where the Ferronorte railroad interlines with the Ferroban railroad, and then headed to the final destination of Santos port (Figure 13, green line). The total rail trip is estimated to be approximately 1,222 kms (763 miles).

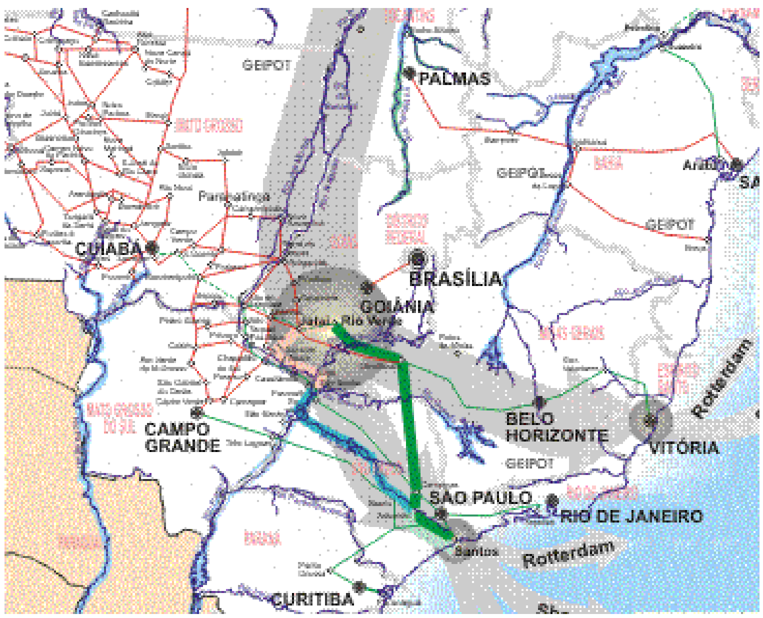


**Figure 13. Improved soybean transportation routes for the State of Goiás**
*Source:* Empresa Brasileira de Planejamento de Transportes (GEIPOT/MT, 2001)

In summary, the expansion of the Ferronorte railroad from Alto Araguaia to Uberlândia will cross the south of Goiás, offering a different transportation mode to important soybean producing cities (Rio Verde, Jataí, Mineiros, etc.). The total railroad transportation cost is calculated to be $18.25/MT, which represents a reduction of

$8.11/MT when compared to the cheapest route (SIFRECA, 2007). Such expansion is expected to boost soybean transportation through trains from the south of Goiás to the Santos port. However, in the Brazilian government Programa de Aceleração do Crescimento (PAC) 2007/2010, investments for such expansion were not included in the budget (DNIT/MT, 2007b).

## The State of Mato Grosso do Sul

The state of Mato Grosso do Sul was originally part of Mato Grosso when it was created in 1977. The state of Mato Grosso do Sul is the seventh largest state in Brazil with 358,158 square kms (223,848 square miles). The neighboring states are Mato Grosso (North), Goiás (North-East), Minas Gerais (East), São Paulo (East), and Paraná (South-East). It also borders Paraguay (South) and Bolivia (West).

The state of Mato Grosso do Sul is the fifth largest soybean producer and exporter in Brazil for 2005/06 (Figure 3 and Table 6). At least five areas within this state produced over 0.20 MMT soybeans in 2005, among which Maracajú and Dourados ranked number one and two with total production of 0.34 and 0.29 MMT, respectively. The production of the southeast of Mato Grosso do Sul, where Maracajú and Dourados are located, accounted for over 61 percent of the state's production (IBGE/MPOG, 2007).

Following the GEIPOT/MT (2001) study and due to its significance to the state, the city of Dourados is the representative origin for the analysis of the current soybean transportation routes for Mato Grosso do Sul. Figure 14 shows the less costly soybean transportation routes for the state of Mato Grosso do Sul, with starting point at Dourados. The first transportation route is by truck from Dourados to the exporting port of Paranaguá (Figure 14, red line). The total road trip is approximately 1,086 kms (678 miles).

An alternative route involves two transportation modes. Trucks loaded with soybeans depart Dourados and travel nearly 487 kms (304 miles) to Ferrovia Paraná (Ferropar) railroad terminal at the city of Cascável, Paraná (Figure 14, pink line) from where transportation continues via railroad. Then, at Guarapuava, the Ferropar railroad interlines with the ALL railroad and head down to the Paranaguá port (approximately 739 kms or 461 miles).

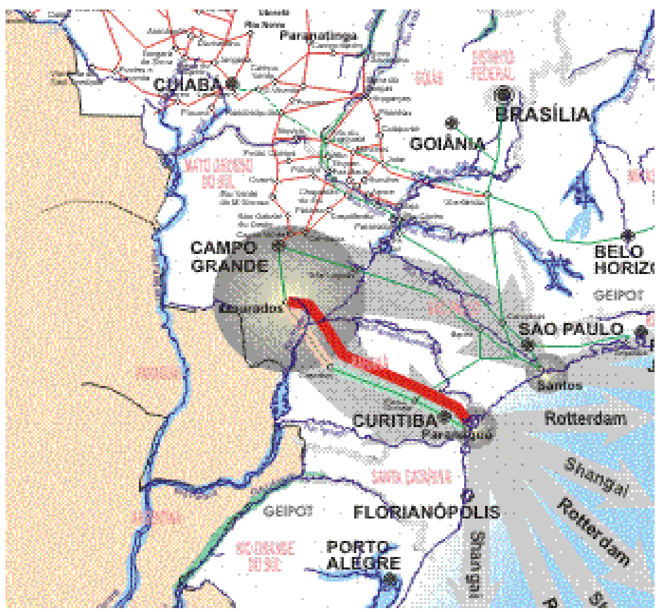


**Figure 14. Current soybean transportation routes for the State of Mato Grosso do Sul**
*Source:* Empresa Brasileira de Planejamento de Transportes (GEIPOT/MT, 2001)

Despite of the large soybean production in the state of Mato Grosso do Sul, it is estimated that a small proportion of soybeans are crushed within the state. As Table 6 shows, in 2006, the crushing capacity of Mato Grosso do Sul was 9,360 MT/ day, a lot less than that of Goiás. Since the largest state in crushing capacity (Paraná) borders with Mato Grosso do Sul (Table 6), it is likely that soybeans are shipped to Paraná to be crushed. Nonetheless, most of the soybeans are likely to be exported. The final exporting ports are the Paranaguá and Santos ports, with the former being most important.

According to GEIPOT/MT (2001), the improvements in transportation infrastructure that are likely to reduce transportation costs for farmers located in Mato Grosso do Sul are illustrated in Figure 15. By expanding the Ferropar rail track to the city of Dourados, the improved route involves only train shipments to the Ferropar railroad which interlines the ALL railroad at Guarapuava for final transport to the exporting port of Paranaguá at the Atlantic Ocean (Figure 15, green line). The total rail trip is approximately 1,155 kms (721 miles).

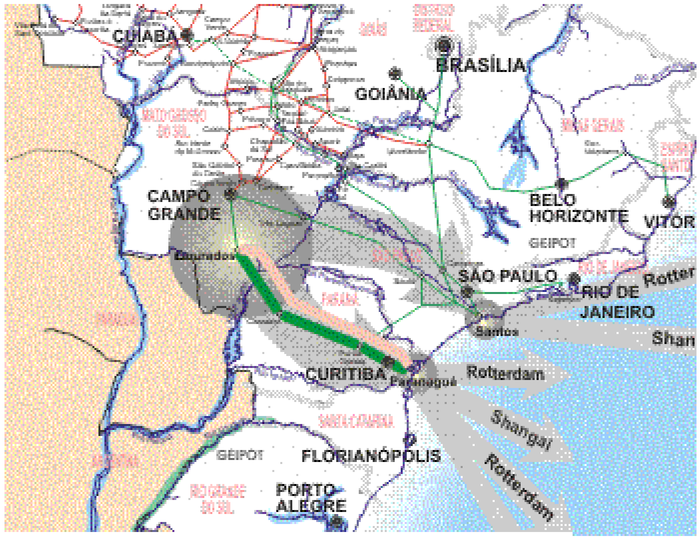


**Figure 15. Improved soybean transportation routes for the State of Mato Grosso do Sul**
*Source:* Empresa Brasileira de Planejamento de Transportes (GEIPOT/MT, 2001)

In 1997, the Ferropar company signed a contract with the Ferroeste, which administrates the operation of the railroad. At the end of 2006, the Ferropar declared bankruptcy and the Ferroeste re-gained the operation of the railroad. Therefore, the expansion of the Ferropar railroad to the city of Dourados is unlikely to be completed by Ferroeste in the near future. In the Brazilian government Programa de Aceleração do Crescimento (PAC) 2007/2010, investments for such expansion were not intended in the budget (DNIT/MT, 2007b). By using data from SIFRECA (2007), this expansion will reduce transportation costs by an estimated $1.50/MT, which is not a relevant improvement compared to current routes.

After reviewing implemented and probable improvements to Brazilian Central-West's transportation infrastructure, table 10 shows the most noteworthy regarding their potential impact on competitiveness.

**Table 10. Evaluated Transportation Improvements, Regions Affected by Improvements, and Estimated Savings of Improvements**

| Proposed Improvement | Impacted Region | Cost Savings ($/MT) |
|---|---|---|
| Tapajós-Teles Pires Waterway | West Mato Grosso | $11.65 |
| BR-163 Highway | North Mato Grosso | $20.00 |
| Mortes-Araguaia Waterway | Northeast Mato Grosso | $11.00 |
| Ferronorte Expansion to Rondonópolis | Southeast Mato Grosso | $1.00 |
| Ferronorte Expansion to Uberlândia | Goiás | $8.11 |
| Ferropar Expansion to Dourados | Mato Grosso do Sul | $1.50 |

Source: Author's estimation. Data from Sistema de Informações de Fretes (SIFRECA, 2007).

# CHAPTER III

# METHODOLOGY

The objectives of this chapter are: (i) to review relevant spatial equilibrium literature relating to quadratic programming models and its application to different commodities and/or countries; (ii) to present a prototype model formulation; (iii) to describe the estimation procedure used to obtain linear excess supply (demand) functions in Brazil, excess demand functions for the importing regions, and the excess supply functions for other exporting countries/regions; (iv) to explain the procedure used to estimate production, export, and consumption by region/state/sub-region in Brazil; and (v) to describe the procedure adopted to estimate the truck, rail, barge, intermodal transfer, port, and ocean transportation costs and port capacity for Brazil.

## Literature Review

There are two types of programming models that have been extensively used by economists to simulate the impact of alternative farm and transportation policies: price exogenous linear programming and price endogenous quadratic programming. The first case assumes fixed commodity prices and quantities, thereby neglecting the interrelationships of aggregate prices and quantities. The latter case recognizes price-quantity interaction, thus addressing spatial or intertemporal equilibrium problems (Fellin, 1993). In this study, the price endogenous assumption is adopted and the literature review is concentrated on quadratic programming models, specifically the spatial equilibrium model.

The price endogenous model was originally developed by Enke (1951) and later Samuelson (1952). It was more fully developed by Takayama and Judge (1971). The general form maximizes the integral of the area underneath the demand curve minus the integral underneath the supply curve, subject to a supply-demand balance. The resultant objective function is generally called consumers' plus producers' surplus.

A common price endogenous model application is the spatial equilibrium model. This model is an extension of the transportation problem, which focuses on minimizing transportation costs between supply and demand points, relaxing the assumption of fixed supply and demand. In this model, production and/or consumption usually occurs in spatially separated regions, each of which have supply and demand relations. In the solution, if the regional prices differ by more than the interregional cost of transporting the commodity, then trade will happen and the price will be driven down to the transport cost. The solution for the model gives results such as who will produce and consume what quantities, and what level of trade will occur (McCarl and Spreen, 2003).

The effects of transportation costs on spatially separated regions are depicted in Figure 16. The initial situation with relatively high transportation costs is represented by the solid line. As the transportation costs are considered, the vertical distance (TC) between the excess supply (ES) and excess demand (ED) represents the price wedge between the importing and exporting countries. This difference is measured based on the intersection of the derived demand ($D_t$) and transport supply ($S_t$) in the transportation sector in Brazil. Additionally, this intersection also determines the corresponding domestic soybean price in Brazil ($P_x$), the price in importing country, and competing exporting countries (both $P_m$).

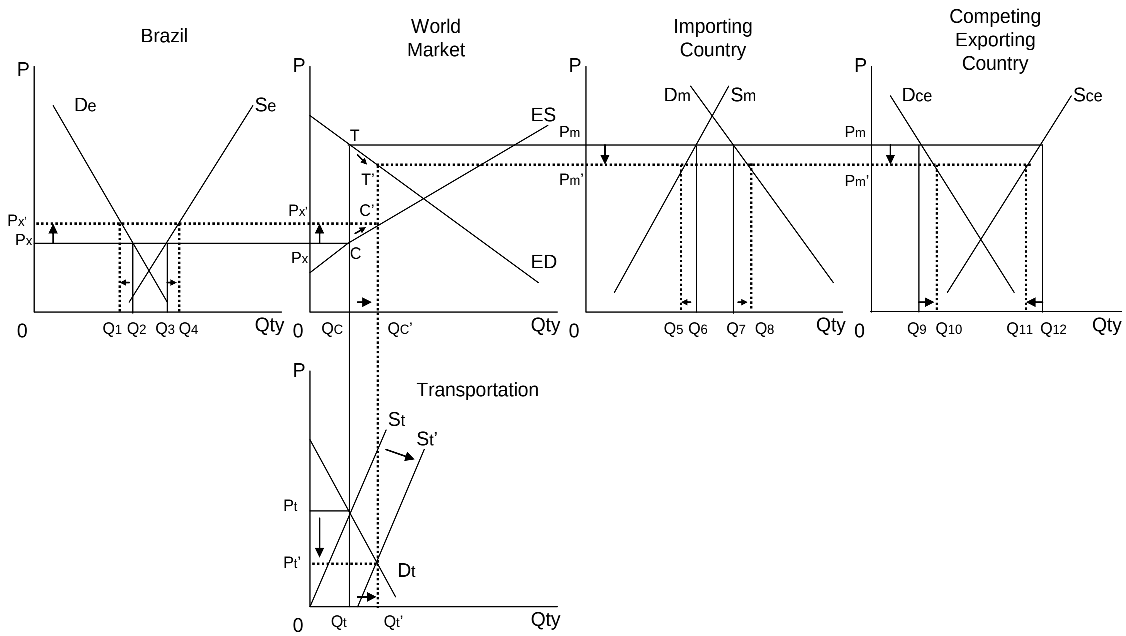


**Figure 16. Effects of transportation costs in international trade of a single commodity**
*Source:* Compiled from Yu et al (2006).

As transportation costs in Brazil are reduced due to improved infrastructure, the transport supply curve shifts downward (from $S_t$ to $S_t$') and, consequently, the transportation costs in Brazil decrease from TC to T'C'. As a result, soybean price and exports in Brazil increase from $P_x$ to $P_x$' and from $Q_2 – Q_3$ to $Q_1 – Q_4$, respectively. For the rest of the world, the soybean price declines which causes an increase in imports from $Q_6$ - $Q_7$ to $Q_5 – Q_8$ and a decrease in competing exports from $Q_9 – Q_{12}$ to $Q_{10} – Q_{11}$.

Total soybean world trade is illustrated in the figure as 0 – $Q_{C'}$, which represents an increase compared to the initial equilibrium condition. The net result of reducing transportation costs in Brazil is increased exports from Brazil, more world trade, but lower levels of exports by competing countries.

The theoretical framework of the spatial equilibrium model was developed by Takayama and Judge (1971). As previously described, the spatial equilibrium problem is mathematically expressed as maximizing the areas under the demand curves minus the areas under the supply curves minus transportation costs.

Based on McCarl and Spreen (2003), suppose that in region i the demand for the commodity is given by

$$P_{di} = f_i\,(Q_{di})$$

where $P_{di}$ is the demand price in region i while $Q_{di}$ is the quantity demanded. Likewise, suppose that the supply function for region i is

$$P_{si} = s_i\,(Q_{si})$$

where $P_{si}$ is the supply price in region i, and $Q_{si}$ the quantity supplied.

The welfare function is defined as the area underneath the demand curve minus the integral underneath the supply curve. The individual welfare function can be expressed mathematically as

$$W_i(Q_{si}^*, Q_{di}^*) = \int_0^{Q_{di}^*} P_{di}\,dQ_{di} - \int_0^{Q_{si}^*} P_{si}\,dQ_{si}\,.$$

The total welfare function across all regions is the sum of the welfare functions in each region less total transport costs. Suppose $T_{ij}$ represents the amount of the commodity shipped from i to j at cost $c_{ij}$. Then the net welfare (NW) is

$$NW = \sum_i W_i(Q^*_{si}, Q^*_{di}) - \sum_i \sum_j c_{ij} T_{ij}.$$

The constraints for the spatial equilibrium model are the restrictions of the linear transportation models. There is a demand balance equation requiring that incoming shipments to region j are greater than or equal to region j demand. Such restriction is expressed mathematically in the following form

$$Q_{di} \leq \sum_i T_{ij} \text{ for all j}$$

and a supply balance requiring that outgoing shipments do not exceed regional supply

$$Q_{si} \geq \sum_i T_{ij} \text{ for all i}$$

The mathematical model that determines the level of production and consumption in each region, the market clearing price in each region, and the amount traded between regions is as follows

$$Max\ NW = \sum_i W_i(Q^*_{si}, Q^*_{di}) - \sum_i \sum_j c_{ij} T_{ij}$$

subject to

$$Q_{di} \leq \sum_i T_{ij} \text{ for all j}$$

$$Q_{si} \geq \sum_i T_{ij} \text{ for all i, and}$$

$$Q_{di}, Q_{si}, T_{ij} \geq 0.$$

If the demand and supply curves are linear and, respectively, downward and upward sloping, i.e.,

$$P_{di} = a_i - b_i Q_{di}, \text{ and}$$

$$P_{si} = c_i + d_i Q_{si},$$

the problem becomes

$$Max \sum_i (a_i Q_{di} - 1/2 b_i Q_{di}^2 - c_i Q_{si} - 1/2 d_i Q_{si}^2) - \sum_i \sum_j c_{ij} T_{ij} \qquad (1)$$

subject to

$$Q_{di} \leq \sum_i T_{ij} \text{ for all j} \qquad (2)$$

$$Q_{si} \geq \sum_i T_{ij} \text{ for all i, and} \qquad (3)$$

$$Q_{di}, Q_{si}, T_{ij} \geq 0. \qquad (4)$$

The quadratic term included in the objective function (1) results in the quadratic programming model. The solution to this problem gives the level of production ($Q_{si}$), the level of consumption ($Q_{di}$), and the level of imports and exports ($T_{ij}$) in each region as well as the level of internal consumption ($T_{ii}$). Price in each region is found by either substituting into the demand function or examining the dual variables.

Many spatial equilibrium models have been developed in the past to analyze agricultural policies, interregional transportation issues, and imperfect market competition which impact international agricultural trade. For further research interest, there is an extensive literature available on international agricultural trade policies and imperfect market competition using spatial equilibrium models such as Shei and Thompson (1977), Anania and McCalla (1991), Cramer et al (1993), Waquil and Cox (1995), Fuller et al (2003), and Devadoss et al (2005). However, the objective of this study is to focus only on interregional transportation issues and how they affect international agricultural trade.

Wilson and Koo (1985) developed a multimarket spatial equilibrium model to evaluate the effectiveness of using alterations in rail rates to stimulate export market development of hard red spring wheat shipments to the Pacific northwest exporting ports. One of the study's scenarios showed that a 20 percent decrease in rail rates from North Dakota to the Pacific northwest exporting ports led to a slight increase in North Dakota wheat producers' revenue and average net price. However, the most important conclusion of their work was that in the case of hard red spring wheat transportation, commodity demands and supplies are relatively inelastic and the transportation cost is small compared to the commodity price. Consequently, decreases in rail rates are not efficient in changing the traditional hard red spring wheat distribution patterns. Additionally, only large changes in rail rates were able to divert traffic from eastern markets, via Duluth and Gulf ports, to the Pacific northwest ports.

An international corn and soybean intertemporal spatial equilibrium model was developed by Fellin (1993) to analyze the economic effects of the traffic congestion on the upper Mississippi and Illinois waterway. The results were that higher barge costs caused by traffic congestion on the upper Mississippi and Illinois waterway would reduce the United States corn and soybean producers' annual revenues by $26.4 million and $16.4 million, respectively. Producing states that would be the most affected are Iowa and Minnesota for both commodities. Furthermore, the volume of corn and soybeans shipped through the waterway to the lower Mississippi port area would decline by 2 MMT of corn and 1.4 MMT of soybeans. Yet, the increase in barge rates would have only a modest impact on the country’s share of the world market for both commodities.

Five years later, Fuller et al (1998) incorporated the hard red spring wheat sector into the spatial, intertemporal equilibrium model developed by Fellin (1993). The objectives of this study were: (i) to analyze the effect of reduced upper Mississippi and Illinois waterway transportation system capacity on the grain (corn and hard red spring wheat) and soybeans sectors; (ii) to estimate how an increase in traffic levels on the upper Mississippi and Illinois waterway affect costs of barge transportation; and (iii) to determine the effect of increasing capacity of selected locks on the upper Mississippi and Illinois rivers.

Results of a study by Fuller et al (1998) estimating the effects of reduced transportation capacity were an annual revenue reduction of $350 million to corn, soybean, and wheat producers. Reductions in transportation capacity would change the grain flow from lower Mississippi river ports to the Great Lakes and Pacific Northwest ports. As for increase in traffic levels on the upper Mississippi and Illinois rivers, it was estimated a grain and soybeans flow diversion from these rivers. Further, traffic increases were projected to reduce combined annual revenues of corn, soybean and wheat producers of $105 million.  It was estimated that upgrading the capacity of the 25 locks located in the waterway would increase income from all commodities combined annual producer revenues of about $60 million given the projected increase in traffic. Although substantial quantities of grain were diverted from the upper Mississippi and the lower Mississippi river ports at higher traffic levels and barge costs, total exports were only modestly impacted due to increases in exports by other ports such as Great Lakes and Pacific northwest ports.

Fellin and Fuller (1998) analyzed whether privatization of Mexico's state-owned railroad, Ferrocarriles Nacionales de Mexico (FNM), would have adverse effects on the United States overland corn, sorghum, and soybean exports to Mexico. Previously-developed spatial, intertemporal equilibrium models of these sectors were utilized to perform such analysis. Results suggested that the privatization of the FNM would cause an increase in the United States grain/soybean exports to Mexico via overland routes. When compared to the pre-privatization analysis, post-privatization analysis estimated an increase of 2.93 MMT of United States grain/soybean overland exports to Mexico. According to the authors, this increase resulted from significant reductions in the railroad costs by privatized carriers and the competitive transportation environment. Under the FNM privatization, the railroad rate was projected to decrease $8/MT (from $27/MT to $19/MT). In summary, the model showed that FNM privatization had the potential to considerably increase United States grain/soybean exports to Mexico. Additionally, the analysis showed an increase in U.S. producer's annual grain/soybean revenues of $42 million per year as a result of privatization.

Fuller et al (2000) investigated the effects of revenue-maximizing Panama Canal management and Canal closure on revenues and exports of the United States corn and soybean producers. Two scenarios were examined: (i) evaluate the effect of increasing Panama Canal tolls; and (ii) Panama Canal closure. Once again, previously-developed spatial, intertemporal models were applied. Analysis showed that increasing tolls would decrease exports via Gulf ports, increase in exports through Pacific northwest ports, reduce quantities transported in the Panama Canal, and adoption of new maritime routes to East Asia via Africa’s Cape of Good Hope. According to the authors, U.S. participation in Asia’s corn and soybean markets would decline and total exports would be reduced approximately 2 percent. In addition, a higher toll would reduce United States corn and soybean revenues of nearly $160 million. If the Canal were closed, it was estimated that the revenues of such commodities would decline by $303 million per year.

Fuller et al (2001) used a previously-developed spatial, intertemporal international corn/soybean equilibrium model to evaluate the effect of recent and expected improvements in transportation and marketing infrastructure in South America on competitiveness in the world corn and soybean markets. Six transportation and marketing infrastructure improvements were investigated: (i) improved efficiency of Brazil and Argentina’s corn/soybean port elevators; (ii) dredging of Argentina’s lower Paraná river ports; (iii) improved navigability of the Paraná-Paraguay waterway; (iv) extension of the Ferronorte railroad into south-central Mato Grosso (Cuiabá); (v) development of the Madeira-Amazon waterway; and (vi) completion of highway BR – 163 to Santarém river port.

After introducing all six improvements into the model, the authors’ results showed important gains to South American soybean and corn producers. As Table 11 presents, South American soybean exports increased 1.29 MMT tons per year, and producer revenues increased about $719 million. The average increase in producer price in exporting countries ranged between $3.94 to $11.79/MT. Argentine corn exports were estimated to increase 1.99 MMT and producer revenues about $385 million per year as a result of all six improvements while average producer price increases $8.72/MT.

**Table 11. Estimated Effects of South America's Transportation and Marketing Improvements on the United States and South American Soybean and Corn Exports, Prices, and Revenues**

| ***Changes in Exports (Million Metric Tons)*** | Soybeans | Corn |
|---|---|---|
| United States | -0.548 | -0.815 |
| Argentina | 0.626 | 1.991 |
| Brazil | 0.483 | - |
| Paraguay | 0.114 | - |
| Bolivia | 0.068 | - |
| ***Changes in Prices ($/Metric Ton)*** | Soybeans | Corn |
| United States | -2.21 | -0.25 |
| Argentina | 6.94 | 8.72 |
| Brazil | 3.94 | - |
| Paraguay | 8.04 | - |
| Bolivia | 11.79 | - |
| ***Changes in Revenues (million dollars)*** | Soybeans | Corn |
| United States | -187.30 | -101.80 |
| Argentina | 335.50 | 385.10 |
| Brazil | 286.70 | - |
| Paraguay | 62.70 | - |
| Bolivia | 34.10 | - |

*Source:* Fuller et al (2001).

The average soybean increase in price in Brazil was lower than for other countries, but the increase in exports and revenues were significant (Table 11). As transportation and marketing improvements were considered in the model, results indicated about 45 percent of Mato Grosso soybean production would be shipped via highway BR-163 to the Santarém river port. Due to the completion of this highway, soybean prices in central Mato Grosso increased $12.22/MT on the average. The Madeira-Amazon waterway was also important, reducing the west-Central Mato Grosso soybean price by $13.28/MT on the average. Also, an extension of the Ferronorte railroad into south-central Mato Grosso induced a relatively modest increase in producer price of $2.24/MT. Overall, in Mato Grosso, the average price increases were about $9.20/MT which was double the increase of Brazil's soybean price increase.

Fuller et al (2001) concluded that the United States experienced a comparatively modest decrease in prices, exports, and revenues as the results of South America's improved transportation and marketing infrastructure. South American producers gain significantly. However, the United States' absolute loss in exports and revenues represented a small proportion (less than 1.4 percent) of producers' total revenues and exports from international corn and soybeans sales before the improvements.

## The Quadratic Programming Model

An international spatial, intertemporal model for soybeans was developed on the basis of quadratic programming model. The model was formed by spatial and temporal dimensions that allow soybeans to move from Brazil producing areas to domestic demand regions and importing countries for each quarter. The United States, Argentina, Rest of South America (Bolivia, Paraguay, and Uruguay), Canada, and India were included in the model as soybean exporting region/countries. The importing countries were China, the European Union (25), Southeast Asia, Mexico, and the Rest of the World.

Brazil’s domestic soybean excess supply, other soybean exporting countries’ excess supply equations as well as other country import demand equations were introduced into the objective function of the model. Brazil’s domestic producing regions/states were linked to local demand locations and to Brazil’s exporting ports through internal transportation modes. Likewise, import demand equations in each import country were incorporated and linked to Brazil’s ports and other exporting countries through ocean transportation costs.

The soybean model was established by 18 excess supply sub-regions/states and eight excess demand regions in Brazil. The 18 soybean excess supply sub-regions/state in Brazil were North, West, Northeast, and Southeast of the state of Mato Grosso, the producing regions in the states of Maranhão and Piauí, the state of Bahia, East and South of Goiás, Northwest, Northeast, and South of Mato Grosso do Sul, the state of Minas Gerais, North and Southwest of Paraná, Northwest and Southwest of Rio Grande do Sul, the state Tocantins, and the state of Rondônia. The excess demand regions in Brazil were represented by the regions of North, Northeast and Southeast (São Paulo, Rio de Janeiro, and Espírito Santo) and the states/sub-regions of Center-North Goiás, the state of Santa Catarina, Southeast Paraná, East Rio Grande do Sul, and Cuiabá in the state of Mato Grosso.

## Development of the Basic Spatial, Intertemporal Equilibrium Model

The spatial, intertemporal equilibrium model was designed to illustrate soybeans transported through Brazil's internal transportation modes. The model took into account soybean movements from excess supply regions to excess demand regions and possible flows to Brazil's port facilities and the transhipment to importing countries. The model incorporated major Brazil excess supply states/regions, domestic excess demand states/regions, internal transportation modes, exporting port facilities, ocean ship transportation, and estimated import demand.

Routinely, a major portion of the excess supply is exported or consumed domestically during the harvest period. The rest of the production is stored for alternative shipment to port terminals or other domestic demand locations. The quantities consumed and supplied per quarter are endogenously determined by the model. No soybean stocks were considered in the model. The assumptions for the model were that soybeans are homogenous commodity, nondiscriminatory trade policies, and system of balanced equations. The objective of the model was to maximize the summation of producer surplus and consumer surplus subtracting transportation and handling costs.

## The Model

A partial equilibrium model was developed that uses quadratic programming to maximize producer and consumer surplus. Through the optimum solution, welfare measures can be achieved as a result of changes in the transportation and handling costs.

The solution gives the level of supply (demand) for each selected excess supply (demand) location in Brazil and other major soybean exporting (importing) countries. Soybean flows from supply locations to domestic demand regions, port areas, or transhipment locations were determined by the optimum solution. The price levels at shipping, transhipment, and final destination locations were captured by either substituting into the demand function or examining the dual variables.

Given linear supply and demand equations for all regions, the objective function and balance restrictions are expressed as:

$$
\begin{aligned}
(1)\ Max\ \ NW\ = \{ & \textstyle\sum_q \{ -\sum_i (\alpha_{iq} + 0.5\beta_{iq} S_{iq}) S_{iq} - \sum_f (\alpha_{fq} + 0.5\beta_{fq} S_{fq}) S_{fq} \\
& + \textstyle\sum_j (\alpha_{jq} - 0.5\beta_{jq} D_{jq}) D_{jq} + \sum_d (\alpha_{dq} - 0.5\beta_{dq} D_{dq}) D_{dq} \} \\
& - \{ \textstyle\sum_m (\sum_i (\sum_j C_{ijm} T_{ijqm} + \sum_b C_{ibm} T_{ibqm} + \sum_r C_{irm} T_{irqm} \\
& + \textstyle\sum_p C_{ipm} T_{ipqm})) + \sum_u \sum_p C_{upm} T_{upm})\} \\
& - \{ \textstyle\sum_b (\sum_u C_{bu} T_{buq} + \sum_p C_{bp} T_{bpq}) \\
& - \textstyle\sum_r (\sum_p C_{rp} T_{rpq}) \\
& - \textstyle\sum_d (\sum_p C_{pd} T_{pd} + \sum_f C_{fd} T_{fdq})\}\}
\end{aligned}
$$

subject to:

(2) $\sum_m (\sum_j T_{ijqm} + \sum_b T_{ibqm} + \sum_r T_{irqm} + \sum_p T_{ipqm}) + G_{qq+1} \leq S_{iq} + G_{q-1q}$ for all i and q;

(3) $\sum_p T_{bpq} + \sum_u \sum_m T_{buq} \leq \sum_i \sum_m T_{ibqm}$ for all b and q;

(4) $\sum_p T_{rpq} \leq \sum_i \sum_m T_{irqm}$ for all r and q;

(5) $\sum_d T_{pdq} \leq \sum_m \sum_i T_{ipmq} + \sum_b T_{bpq} + \sum_r T_{rpq} + \sum_u T_{upq}$ for all p and q;

(6) $\sum_m \sum_u T_{ujmq} \geq D_{jq}$ for all j and q;

(7) $\sum_p T_{pdq} + \sum_f T_{fdq} \geq D_{dq}$ for all d and q;

(8) $\sum_d T_{fdq} + R_{qq+1} \leq S_{fq} + R_{qq-1}$ for all f and q;

(9) $\sum_p T_{pd} \leq PC_p$ for all p;

(10) $T, S, D \geq 0$ for all i, j, f, q, d, b, p, and r

where equation (1) is the net welfare interpreted as consumer surplus plus producer surplus minus transportation costs. From (2) to (5), all equations are supply balance constraints. Equation (2) constrains the soybean flow from i excess supply region to all receiving and transhipment points that is less than or equal to the quantity supplied at location i for all four quarters of the year. Equation (3) limits transhipments at barge-loading location so that the quantity shipped from each location is less than or equal to total quantities received for every quarter. Equation (4) constrains transhipments at rail-loading terminals so that the quantity shipped from each location is less than or equal to total quantities received for every quarter. Equation (5) constrains soybean shipments at each Brazil port to be less than or equal to quantity received at the ports by different inland transportation modes for every quarter.

From equation (6) to (8), all equations are demand balanced constraints. Equation (6) limits quantity shipped by different inland modes to each demand location to be at least equal to or greater than the quantity demanded at each demand location for every quarter of the year. Equation (7) constrains quantity imported by each importing country to be at least equal to or greater than the quantity demanded for each quarter. Equation (8) limits quantity shipped from exporters f to all importing countries to be less than or equal to the quantity supplied at f for all quarters of the year. Equation (9) constrains soybean exports by port to less than or equal to its capacity. Equation (10) represents the non-negativity conditions. Table 12 shows the subscripts, parameters, and variables included in the formulated model.

**Table 12. Subscripts, Parameters and Variables Included in Formulated Model**

| ***Subscripts*** | ***Definition (quantity)*** |
|---|---|
| q | quarter (1,2,3,4) |
| i | Brazil excess supply locations (1,2,3…18) |
| f | foreign exporting regions (1,2,3…6) |
| j | Brazil excess demand locations (1,2,3…8) |
| d | Foreign importing countries (1,2,3…5) |
| m | Inland modes of transportation (1,2,3) |
| b | Barge loading locations (1,2,3) |
| u | Barge unloading locations (1) |
| r | Rail-loading terminal (1,2,3…8) |
| p | Brazil ports (1,2,3…8) |
| ***Parameters*** | ***Definition*** |
| C | Transportation costs per MT by the various modes |
| ***Variables*** | ***Definition*** |
| $S_i$ | Brazil excess supply regions |
| $S_f$ | Foreign excess supply regions |
| $D_j$ | Brazil excess demand regions |
| $D_d$ | Foreign excess demand regions |
| T | Soybean flow in MT between nodes |
| G | Quarterly quantities stored in Brazil |
| R | Quarterly quantities stored in other major exporting countries |
| PC | Port capacity |

## Estimation of the Excess Supply (Demand) Equations

The following equation was used to estimate excess supply elasticity for exporting regions (Shei and Thompson, 1977):

(11) $E_{es} = E_s(Q_p/Q_e) – E_d(Q_d/Q_e)$

where, $E_{es}$ is the excess supply elasticity of a region, $E_s$ is the own-price supply elasticity of a region, $Q_p$ is the quantity produced in a region, $Q_e$ is the quantity exported from a region, $E_d$ is the own-price demand elasticity of a region, and $Q_d$ is the quantity demanded or consumed in a region. Since the own-price elasticity is not price responsive in the short-run, then the first term in (11) is zero, and $E_{es}$ is dependent on quantity domestically demanded, exported, and the demand elasticity,

Similar to the excess supply elasticity equation, the excess demand elasticity equation is represented as (Shei and Thompson, 1977):

(12) $E_{ed} = E_s(Q_p/Q_i) + E_d(Q_d/Q_i)$

where, $E_{ed}$ is the excess demand elasticity of a region, $E_s$ is the own-price supply elasticity of a region, $Q_p$ is the quantity produced in a region, $Q_i$ is the quantity imported into a region, $E_d$ is the own-price demand elasticity of a region, and $Q_d$ is the quantity demanded or consumed in a region. As in the excess supply elasticity case, the own-price supply elasticity was assumed to be equal to zero which is consistent to the short-run nature of the model.

The soybean own-price demand elasticity for each sub-region/state was assumed to be equal to Brazil's own-price demand elasticity. The equation used to estimate Brazil's own-price soybean demand elasticity is the following (Piggott and Wohlgenant, 2002):

$$(13)\ \eta_b = s^d \left[ \frac{P_b}{\frac{\alpha P_m}{\eta_m} + \frac{\beta P_o}{\eta_o}} \right] + (1 - s^d)\eta_{xb}\varepsilon_{fb}$$

where $\eta_b$ is the elasticity of total demand for soybeans, $s^d$ is the average share of domestic disappearance of soybeans for the period in analysis[9], $P_b$ is the average soybean export price for the period in analysis, $\alpha$ is the yield of soymeal, $P_m$ is the average soymeal export price for the period in analysis, $\eta_m$ is the elasticity of meal demand, $\beta$ is the yield soyoil, $P_o$ is the average soyoil export price for the period in analysis, $\eta_o$ is the elasticity of soyoil demand, $\eta_{xb}$ is the elasticity of export demand for soybeans, and $\varepsilon_{fb}$ is the elasticity of price transmission. By substituting the estimated values (Appendix B) into the equation (13), the soybean own-price demand elasticity for Brazil was calculated to be -0.20.

The soybean own-price demand elasticities for the United States, Argentina, and rest of South America, Canada, and India were adopted from several sources. For the United States, the soybean own-price elasticity was -0.38 (Piggott and Wohlgenant, 2002). The soybean own-price demand elasticities for Argentina and rest of South America were assumed to be -0.25 for both countries (FAPRI, 2007). For Canada and India, the own-price demand elasticity was -0.25 and -0.30, respectively. With respect to importing countries, the soybean own-price demand elasticities were -0.20 and -0.245 for China and European Union, respectively, according to FAPRI (2007). As for Southeast Asia, the own-price demand elasticity was assumed to be equal to -0.37 which is Japan's elasticity (FAPRI, 2007). As for Mexico and the Rest of the World, the own-price elasticities were assumed to be -0.24 and -0.36, respectively (FAPRI, 2007)

[9] $S^d = (B^d/B^s)$ where $B^d$ is the total soybean supply minus total soybean exported and $B^s$ is total soybean supply.

Given the previously mentioned supply (demand) elasticities, estimation of the intercept and slope parameters for the supply (demand) equations is described. These parameters are introduced into the objective function of the model (Equation 1). According to Fellin (1993), elasticity can be expressed as:

(14) $E_{ei} = \delta Q/\delta P\ (P/Q)$

where $E_{ei}$ is the excess supply (demand) elasticity, $\delta Q/\delta P$ is the first derivative of the excess supply (demand) function, and P and Q are average price and quantity, respectively. A linear supply (demand) function can be described as:

(15) $Q = \alpha + \beta P$

where $\alpha$ and $\beta$ are the intercept and slope coefficients. Then $\alpha$ and $\beta$ can be calculated as follows:

(16) $E_{ei} = \beta\ P/Q$,

(17) $\beta = E_{ei}\ Q/P$,

(18) $\alpha = Q - \beta P$.

## Estimating Production and Consumption for the Excess Supply (Demand) Regions in Brazil

In order to estimate production and consumption of soybeans in excess supply (demand) regions in Brazil, several efforts were conducted based on data from IBGE/MPOG (2007), ABIOVE (2007), and FAS/USDA (2007a).

First, the production share of different regions/states in Brazil was estimated for 2004 and 2005 with data from IBGE/MPOG (2007). The share was then used to estimate the supply and total domestic consumption. Supply was composed by production, beginning stock, and imports. Since there is no data for beginning stock and imports on city-level, these values were obtained by multiplying the share by the total beginning stocks and total imports for Brazil, which was sourced from the FAS/USDA (2007a) for 2005/06. The production by region was also a multiplication of production share (IBGE/MPOG, 2007) and the total production (FAS/USDA, 2007a for 2005/06). The same procedure was applied to calculate the ending stocks.

By adding crushing and seed quantities, the total domestic consumption was estimated. The number of crushing plants by each region was retrieved from ABIOVE (2007) and was assumed to represent the crushing share of these regions. Then, by multiplying the total quantity crushed, with source from FAS/USDA (2007a) to the calculated crush share, consumption of each region was quantified.

Table 13 shows the total supply, total domestic consumption, and surplus/deficits by region in Brazil. Surplus/deficits were calculated by subtracting the total consumption and ending stock from the total supply for each region. If the final value is positive, the region has a surplus and thus an excess supply. On the contrary, if the final value is negative, the region has a deficit and thus an excess demand. The largest surpluses occur for the North and West of Mato Grosso. The largest deficits occur for Cuiabá, Mato Grosso, and the region that comprises the states of São Paulo, Rio de Janeiro, and Espírito Santo. By summing up the surplus/deficit, the total exports from Brazil for 2005/06 were obtained, which match with the number given by FAS/USDA (2007a).

**Table 13. Estimated Soybean Supply, Consumption, and Surplus/Deficit for Excess Supply and Demand Regions in Brazil (Metric Tons)**

| State/Region | Share | Supply | Consumption | Surplus /Deficit |
|---|---|---|---|---|
| Maranhão and Piauí | 0.028 | 2087.98 | 567.02 | 1047.76 |
| Bahia | 0.047 | 3494.20 | 1221.54 | 1480.77 |
| Center-North Goiás | 0.008 | 567.22 | 551.67 | -113.00 |
| East Goiás | 0.018 | 1329.76 | 317.00 | 711.40 |
| South Goiás | 0.107 | 7923.98 | 3223.25 | 2904.91 |
| Northwest Mato Grosso do Sul | 0.018 | 1329.25 | 667.25 | 360.74 |
| Northeast Mato Grosso do Sul | 0.012 | 878.86 | 649.53 | 30.14 |
| South Mato Grosso do Sul | 0.040 | 2923.59 | 729.98 | 1531.02 |
| Minas Gerais | 0.056 | 4103.15 | 1462.31 | 1710.94 |
| SP, RJ, ES[1] | 0.035 | 2607.84 | 3335.08 | -1318.25 |
| Southeast Paraná | 0.030 | 2210.83 | 2251.82 | -542.03 |
| Southwest Paraná | 0.107 | 7876.23 | 3093.25 | 2997.98 |
| North Paraná | 0.059 | 4360.70 | 1717.88 | 1654.55 |
| Santa Catarina | 0.012 | 915.60 | 831.13 | -123.03 |
| Northwest Rio Grande do Sul | 0.053 | 3926.77 | 2685.29 | 351.55 |
| Southwest Rio Grande do Sul | 0.017 | 1225.68 | 48.22 | 899.68 |
| East Rio Grande do Sul | 0.009 | 701.26 | 1714.78 | -1172.45 |
| Tocantins | 0.015 | 1141.71 | 44.92 | 838.04 |
| Rondônia | 0.004 | 290.48 | 11.42 | 213.22 |
| North Brazil | 0.004 | 276.51 | 405.08 | -191.23 |
| Northeast Brazil | 0.000 | 2.34 | 78.93 | -77.12 |
| North Mato Grosso | 0.119 | 8749.93 | 344.26 | 6422.67 |
| West Mato Grosso | 0.094 | 6974.03 | 274.39 | 5119.11 |
| Northeast Mato Grosso | 0.027 | 1994.01 | 78.45 | 1463.65 |
| Southeast Mato Grosso | 0.080 | 5941.95 | 2559.59 | 2035.73 |
| Cuiabá Mato Grosso | 0.000 | 0.00 | 2325.80 | -2325.80 |
| Total | | 73834.00 | 31190.00 | 25911.00 |
| FAS/USDA (2007a) | | 73834.00 | 31190.00 | 25911.00 |

[1]São Paulo, Rio de Janeiro, Espírito Santo.

For the exporting countries, the data for production, consumption, and exports were sourced from FAS/USDA (2007a). In 2005/06, the production for the United States, Argentina, and rest of South America was 90.42 MMT, 58.04 MMT, and 6.85 MMT, respectively. Canada and India production are estimated to be 3.84 MMT and 7.09 MMT, respectively. In the same year, the consumption for the United States, Argentina, and the Rest of South America was 52.41 MMT, 33.34 MMT, and 3.37 MMT, respectively. Consumption was estimated to be 2.02 MMT and 6.97 for Canada and India, respectively.

Following the same procedure to estimate the surplus/deficit for Brazil, surplus/deficit for the exporting countries was computed. The U.S. surplus was 38.00 MMT in 2005/06. The surplus for Argentina and the Rest of South America was estimated to be approximately 24.70 MMT and 3.47 MMT, respectively. The estimated surplus for Canada was 1.81 MMT and only 0.11 MMT was estimated for India.

The deficits for the importing countries in 2005/06 were also estimated by following the same procedure. The deficits for EU, China, and Southeast Asia were estimated to be 13.95 MMT, 28.31 MMT, and 11.15 MMT, respectively. The deficit for Mexico was calculated to be 3.66 MMT. With respect to the Rest of the World, the deficit was 6.39 MMT. All these deficits were calculated based on the data from FAS/USDA (2007a).

## Transportation, Intermodal Transfer, and Port Capacity and Costs

This sub-section demonstrates how the transportation costs parameters were calculated and incorporated into the model.

*Truck Cost*

The truck costs in this study were calculated based on the monthly data from SIFRECA (2007) for the years 2003/2004. Such costs were estimated with a linear equation based on the distance between shipping points and receiving locations. The following equation was estimated and served as a tool to measure new truck transportation routes:

$$US\$/MT = 5.54 + 0.0207Kms - 1.73DQ1 + 1.36DQ2 - 1.12DQ3$$

where the intercept represented the fixed cost (loading and unloading costs) in dollars per MT and the slope accounted for the variable cost per MT/kilometer (transportation costs). DQ1, DQ2, and DQ3 are dummy variables that represent seasonality. The signs for the dummy variables were as expected. The harvest quarter, DQ2, had a positive coefficient which means a higher truck cost is charged to transport soybeans. The R-square for this equation was 0.7936. The intercept and the coefficient for the Kms were significant at the 0.01 level. The dummy variables DQ1 and DQ2 were significant at the 0.05 level and DQ3 was significant at the 0.10 level.

*Rail Cost*

The rail costs were also estimated using the monthly data from SIFRECA (2007) for the years 2003/2004. Two rail cost equations were estimated to represent distances less than or greater than 700 kms for eight routes. The rail cost equation for distances under 700 kms was the following:

US$/MT = 3.80 + 0.014Kms – 0.003DCasParDist + 0.006DATSanDist – 0.005DPFSaoDist

where the intercept was the fixed cost (terminal cost) in dollars per MT, the slope was the variable cost per MT/kilometer (transportation costs). Each dummy variable in the equation represented a different origin-destination travel distance over 700 kms. DCasPar was a dummy for the origin-destination Cascável-Paranaguá multiplied by the distance (736 kms), DATSan was a dummy for the origin-destination Alto Taquari-Santos times distance (1,295 kms), and DPFSao was a dummy for the origin-destination Porto Franco-São Luís times distance (713 kms). Also, the origin-destination for Uberlândia-Vitória (1,313 kms) was represented in the intercept. The coefficient for the dummy variables was the change in magnitude in the slope for the specific route. In other words, it represents the variable cost per MT/kilometer for the mentioned route. The R-square for this equation was 0.786. The intercept and all variables had coefficients significant at the 0.01 level.

In order to estimate the equation for distance greater than 700 kms, the same procedure was adopted as that for distance less than 700 kms. Dummy variables represented origin-destination routes that had travel distance under 700 kms. The rail cost equation for travel distance greater than 700 kms was the following:

US$/MT = -11.62 + 0.031Kms + 0.003DCasAraDist + 0.017DCasPGDist + 0.028DCamParDist + 0.021DMarParDist + 0.018DPedSanDist where the slope was the variable cost per MT/kilometer, DCasAra was a dummy for the origin-destination Cascável-Araucária times distance (606 kms), DCasPG was a dummy for the origin-destination Cascável-Ponta Gross times distance (387 kms), DCamPar was a dummy for the origin-destination Cambé-Paranaguá multiplied by the distance (459 kms), DMarPar was a dummy for the origin-destination Maringá-Paranaguá times distance (497 kms), DPedSan was a dummy for the origin-destination Pederneiras-Santos multiplied by the distance (490 kms). The coefficients for the dummy variables represented the variable cost per MT/kilometer for a specific route. The R-square for this equation was 0.912. Once again, the intercept and all variables had coefficients significant at the 0.01 level.

*Barge Cost*

Waterways are underutilized in Brazil and account for only 13 percent of soybeans transported (Table 8). The barge system is considered to be the most efficient soybean transportation mode for long distance hauls. The barge cost equation was also estimated using the monthly data from SIFRECA (2007) for the years 2003/2004. The following equation represents the barge costs in Brazil:

$$US\$/MT = -0.91 + 0.014\ Kms$$

where the slope was the variable cost per MT/kilometer. The R-square for this equation was 0.86 and the coefficient for the Kms variable was significant at the 0.01 level.

*Ocean Freight Cost*

The ocean freight rates for Brazilian soybean export ports to Hamburg (or Rotterdam) and Shanghai importing ports were based on the AMS/USDA (2007a), which were originally compiled by SIFRECA. Due to lack of data, all exporting ports were assumed to have the same ocean freight cost to the ports of Hamburg and Shanghai as Santos port. Only Paranaguá had a different ocean freight rate. Table 14 shows the quarterly costs of transporting soybeans to Hamburg and Shanghai for 2006.

**Table 14. Quarterly Ocean Freight Chargers for Brazil Soybean Export Ports in 2006, US$/Metric Ton**

| Exporting ports | Importing ports | |
|---|---|---|
| Santos, São Paulo | Hamburg, Germany | Shanghai, China |
| Quarter 1 | 39.51 | 50.13 |
| Quarter 2 | 36.91 | 44.80 |
| Quarter 3 | 50.24 | 60.98 |
| Quarter 4 | 60.40 | 73.32 |
| Average | 46.77 | 57.31 |
| Paranaguá, Paraná | Hamburg, Germany | Shanghai, China |
| Quarter 1 | 38.51 | 49.13 |
| Quarter 2 | 35.91 | 43.80 |
| Quarter 3 | 49.24 | 59.98 |
| Quarter 4 | 59.40 | 72.32 |
| Average | 45.77 | 56.31 |

*Source:* AMS/USDA (2007a).

Olowolayemo (2007) collected data for ocean freight charges from US Gulf ports to importing ports at Europe (Rotterdam) and Japan (Yokohama). The Yokohama port in Japan was used as proxy for Shanghai, China. Additionally, due to lack of data a proxy was also used for Argentina. The Rosario port, Argentina, was assumed to have the same ocean freight charges as Santos port in Brazil. In 2006, the quarterly ocean freight charges for US Gulf port to Rotterdam, Netherlands, were for the first and second quarter $19.53/MT and $20.13/MT, respectively. For the other two quarters, charges were $26.87/MT and $29.60/MT. The quarterly charges from US Gulf port to Yokohama were $35.71/MT and $35.52/MT for the first and second quarters, respectively. For the same ocean route, the third and fourth quarters' freight charges were $44.88/MT and $50.24/MT, respectively.

*Port Charges and Capacity and Intermodal Tranfer Costs*

The port charges and capacity for the Brazilian exporting ports and intermodal transfer costs were both based on a study performed by Martins and Lemos (2006). Table 15 shows the port charges and capacity estimated by the authors for the soybean exporting ports in Brazil. For every single transhipment point, intermodal transfer costs were estimated at US$ 1.50/MT.

**Table 15. Port Charges ($/Metric Ton) and Capacity (Million Metric Tons)**

| Ports | Charges | Capacity |
|---|---|---|
| Santos | 13.20 | 15.00 |
| Paranaguá | 10.80 | 11.00 |
| Vitória | 7.20 | 4.00 |
| São Francisco do Sul | 8.40 | 2.50 |
| Ilhéus | 7.20 | 3.00 |
| Itacoatiara | 6.00 | 3.00 |
| Santarém | 6.00 | 15.00* |
| Itaqui | 6.00 | 6.00 |

* Port capacity was assumed to be greater than the original value.
*Source:* Martins and Lemos (2006).

Port capacity plays a major role in the model development. Without this constraint, ports with more efficient routes become the main recipient. In other words, if one excess supply region has only two main routes, its production will be shipped entirely through the less costly one. This is also described as a corner solution in linear programming. For example, by combining the port charges and transportation costs to the Itacoatiara port, it becomes the most attractive exporting port. As the port capacity is forced into the model, soybeans, which were supposed to be sent to Itacoatiara, are shipped through other routes to different ports.

# CHAPTER IV

# MODEL VALIDATION

This chapter presents the validation procedure for the spatial equilibrium model. According to McCarl and Spreen (2003), model validation is a necessary procedure in any empirical analysis. Validation is often done in quadratic programming models vis-à-vis improving model performance and problem insight. The first part compares Brazil's model-estimated port receipts of soybean by modes of transportation with historical modal shares. The second section compares the model-generated flows to Brazil's ports with the actual flow data. In the third section, model-estimated exports (imports) of the six exporting (importing) regions are compared with actual data. The last section presents the comparison between the model-estimated shadow prices at each excess supply or demand region with the historical data. By validating the model, it serves as the base for comparing before and after improved transportation infrastructure in Brazil.

## Flows to Brazil's Ports by Transportation Mode

As it was analyzed in Chapter I, truck is the most common used transportation mode in Brazil. As Table 8 shows, almost 57 percent of the soybeans are transported to exporting ports by trucks. Railroad is the other mode employed to move soybean to ports, representing 36 percent of the total transportation. Barge is used only seven percent. The model-estimated flows to Brazil's ports by these three transportation modes are 63, 25, and 12 percent for truck, railroad, and barge, respectively.

According to the model results, most of the soybeans carried to port by railroad were hauled by the railroads connecting ports of Paranaguá (2.98 MMT), Itaqui (1.89 MMT), and Vitória (1.73 MMT), which are located in the states of Paraná, Maranhão, and Espírito Santo, respectively. The Santos port had insignificant shipments of approximately 35 thousand MT which was carried by truck and rail. Such low quantity is due to more expensive truck-rail combination from regions in Mato Grosso than to only truck transportation. Therefore, nearly 7.88 MMT of soybeans were moved to Santos solely by truck. At the ports of São Francisco do Sul and Rio Grande located in South Brazil with short farm-to-port distances all flows were carried by trucks. Barge movements were made only through the Madeira-Amazon waterway in North Brazil. The total quantity transported through this waterway was 3.0 MMT. This quantity is equivalent to the port capacity of Itacoatiara, located in the state of Amazonas, according to Martins and Lemos (2006).

Despite some disparities between the actual data and model-estimated flows to exporting ports, model projections tend to approximate actual shares of most ports' flows, particularly, as it relates to the use of truck mode for shipments to ports in South and Southeast Brazil. It also indicates the importance of the Madeira-Amazon waterway for the West of Mato Grosso.

## Soybean Transhipments at Brazil's Ports

The model's estimates of soybean transhipments at Brazil's ports are compared with actual transhipments at these ports for 2005 by using the data from the

SECEX/MDIC (2007). It is important that projected transhipments at all selected ports to be almost identical to the actual data. Table 16 below shows total shipments estimated by the model which represented approximately 79 percent of actual flows from the Brazil's ports. Actual data shows Santos and Paranaguá as the main ports regarding soybean exports, accounting for nearly 58 percent of Brazil's exports in 2005. The model's estimates for these two ports together are overestimated by 12 percent altogether. The estimates for the ports of Vitória, São Francisco do Sul, and Itaqui were approximate to the actual data.

**Table 16. Comparison of Actual Soybean Flows and Model Flows at Different Ports in Brazil (Thousand MT)**

| Ports | Model Estimates | Actual Data[1] | Absolute Deviation | Deviation (%) |
|---|---|---|---|---|
| Santos | 7906.46 | 7342.89 | 563.57 | 7.68 |
| Paranaguá | 6166.74 | 5207.52 | 959.22 | 18.42 |
| Itacoatiara | 3000.00 | 1400.59 | 1599.41 | 114.20 |
| Vitória | 2337.46 | 2845.14 | -507.68 | -17.84 |
| Itaqui | 1895.81 | 1676.62 | 219.19 | 13.07 |
| Ilhéus | 1416.99 | 91.43[2] | 1325.56 | 1449.81 |
| São Francisco do Sul | 2500.00 | 2480.73 | 19.27 | 0.78 |
| Rio Grande | 899.73 | 487.34 | 412.39 | 84.62 |
| Total | 26123.19 | 21532.26 | 4590.93 | 21.32 |

[1] Actual data was retrieved from SECEX/MDIC (2007) for 2005 except Ilhéus port which was sourced from Normali (2007).

The model overestimated soybean exports via the Itacoatiara port through the Madeira-Amazon waterway by about 114 percent. This might be explained, in part, by the port capacity that was assumed to be 3 MMT (annual). In other words, the port capacity forced soybeans to be shipped to other ports as it reached the capacity. The Rio Grande port was also overestimated significantly. In 2004/05, the state of Rio Grande do Sul, the main exporter through this port, suffered one of the worst droughts in history. According to the data from IBGE/MPOG (2007), the soybean production for Rio Grande do Sul in 2004 was 5.54 MMT and, due to the drought, the production for 2005 was estimated at 2.44 MMT.

According to the model, the port of Ilhéus was overestimated by more than 1.32 MMT. A shallow port draft at this port might be attributed to the overestimation, which was not included in the model. By having a shallow draft, the port is not capable of accommodating large vessels that travel long distance carrying bulk shipments (i.e. to ports of Shanghai, China, and Yokohama, Japan). Therefore, it is expected that soybeans from Bahia will be transported to the ports of Santos and Paranaguá in Southeast Brazil or Itaqui port located in the state of Maranhão.

## Domestic Consumption and International Markets

According to FAS/USDA (2007a), the total domestic consumption of soybean for Brazil was 31.19 MMT in 2005/06 MY. The model-estimated total domestic consumption underestimated the actual domestic consumption by 0.70 percent (0.22 thousand MT). Regarding total domestic soybean supply, model-projected results overestimated the FAS/USDA (2007a) actual data of 73.834 MMT by 0.0858 MMT, which is equivalent to deviation of 0.01 percent.

For the exporting countries in this model, the total international soybean trade was estimated by FAS/USDA (2007a) to be 63.47 MMT for the 2005/06 MY, whereas the model estimations were 63.13 MMT in the total, an underestimation of 0.55 percent (Table 17). Overall, suggested exports by the model by country/region were approximate to the actual data with the exception of India. It also noteworthy to mention Brazil exports were overestimated and the United States were underestimated, which indicates that Brazil is the leading soybean exporter.

**Table 17. Comparison of Model-Estimated Exports and Actual Exported Quantity for Different Regions (Thousand MT)**

| Exporting Region | Model Estimates | Actual Data[1] | Absolute Deviation | Deviation (%) |
|---|---|---|---|---|
| USA | 25127.39 | 25778.00 | -650.61 | -2.52 |
| Brazil | 26123.19 | 25911.00 | 212.19 | 0.82 |
| Argentina | 7325.89 | 7249.00 | 76.89 | 1.06 |
| Rest of South America | 3229.46 | 3205.00 | 24.46 | 0.76 |
| Canada | 1323.40 | 1326.00 | -2.60 | -0.20 |
| India | 0.00 | 9.00 | -9.00 | -100.00 |
| Total | 63129.33 | 63478.00 | -348.67 | -0.55 |

[1] FAS/USDA (2007a).

Soybean imports by the importing countries were also compared with the historical data sourced from FAS/USDA (2007a) for the 2005/06 MY (Table 18). The largest soybean importer in the world is China, followed by the EU. The model was the most accurate when predicting imports by China. Although the model’s imports by the EU were underestimated, the difference of -1.01 percent is considered insignificant.

Mexico's imports were the most underestimated with a -3.60 percent deviation. In general, the model's estimation was relatively close to the historical data.

**Table 18. Comparison of Model-Estimated Imports and Actual Imported Quantity for Different Regions (Thousand MT)**

| Importing Region | Model Estimates | Actual Data[1] | Absolute Deviation | Deviation (%) |
|---|---|---|---|---|
| EU | 13810.65 | 13952.00 | -141.35 | -1.01 |
| China | 28319.05 | 28317.00 | 2.05 | 0.01 |
| Southeast Asia | 11146.23 | 11151.00 | -4.77 | -0.04 |
| Mexico | 3535.14 | 3667.00 | -131.86 | -3.60 |
| ROW | 6318.26 | 6391.00 | -72.74 | -1.14 |
| Total | 63129.33 | 63478.00 | -348.67 | -0.55 |

[1] FAS/USDA (2007a).

## Shadow Prices

As it was seen in the methodology chapter, the combination of shadow prices and quantities that are generated by solving the spatial equilibrium model represent the increase in total benefit that occurs when a marginal unit is demanded by an excess demand region. Therefore, the model gives the shadow prices in the excess supply and demand regions. The actual prices at the excess supply and demand regions are contrasted with model-generated shadow prices vis-à-vis model validation.

First, estimated soybean prices in the 18 excess supply regions in Brazil are compared to actual price reported by AMS/USDA (2007a) for 2006. Table 19 presents the model-generated shadow prices and a comparison with historical prices. Due to the lack of data for some states, actual prices for the state of Bahia, Maranhão/Piauí, Goiás, Mato Grosso do Sul, and Tocantins were assumed to be equal to $189.63 which is the price for the state of Goiás. These states were considered to have the same price as Goiás based on average distance from farm to port. Similarly, the price for the state of Rondônia was assumed to be the same as the state of Mato Grosso.

**Table 19. Comparison of Soybean Shadow Prices and Average Market Price at Different Excess Supply Regions in Brazil ($/MT)**

| Supply Region | Model Estimates | Actual Data[1] | Absolute Deviation | Deviation (%) |
|---|---|---|---|---|
| North Mato Grosso | 171.90 | 164.88 | 7.02 | 4.26 |
| West Mato Grosso | 172.50 | 164.88 | 7.62 | 4.62 |
| Southeast Mato Grosso | 184.60 | 164.88 | 19.72 | 11.96 |
| Northeast Mato Grosso | 183.45 | 164.88 | 18.57 | 11.26 |
| Maranhão e Piauí | 204.91 | 189.63 | 15.28 | 8.06 |
| Bahia | 198.13 | 189.63 | 8.50 | 4.48 |
| East Goiás | 193.43 | 189.63 | 3.80 | 2.00 |
| South Goiás | 194.05 | 189.63 | 4.42 | 2.33 |
| Northwest Mato Grosso do Sul | 194.68 | 189.63 | 5.05 | 2.66 |
| Northeast Mato Grosso do Sul | 196.49 | 189.63 | 6.86 | 3.62 |
| South Mato Grosso do Sul | 194.82 | 189.63 | 5.19 | 2.74 |
| Minas Gerais | 200.97 | 189.63 | 11.34 | 5.98 |
| Southwest Paraná | 211.01 | 213.81 | -2.80 | -1.31 |
| North Paraná | 208.00 | 213.81 | -5.81 | -2.72 |
| Northwest Rio Grande do Sul | 214.05 | 210.34 | 0.24 | 1.76 |
| Southwest Rio Grande do Sul | 211.42 | 210.34 | -2.39 | 0.51 |
| Tocantins | 199.47 | 189.63 | 9.84 | 5.19 |
| Rondônia | 180.97 | 164.88 | 16.09 | 9.76 |

[1] AMS/USDA (2007a).

As Table 19 indicates, the model overestimated most of the historical prices, with exception of the regions located in the state of Paraná. However, such differences were less than five percent. The prices for the Southeast and Northeast regions in Mato Grosso were overestimated by more than 10 percent. This can be explained by distance of these regions to the ports compared to the North and West regions for the same state. In general, the model's shadow prices are close representations of the historical data.

The eight excess demand regions in Brazil were also used to compare shadow prices with historical prices. Prices for those regions were also retrieved from the AMS/USDA (2007a) and some of them had to be assumed equal to others state where similar transportation costs occur.

Table 20 indicates the model-estimated shadow prices and the historical data. The largest percentage deviation occurred in the North of Brazil demand regions. The lowest discrepancy is in the Southeast Paraná region. Only one price was underestimated by the model, which was the price for the São Paulo, Rio de Janeiro, and Espírito Santo region. For the excess supply regions, the shadow prices generated by the model are well representations of the historical data in general.

**Table 20. Comparison of Soybean Shadow Prices and Average Market Price at Different Excess Demand Regions in Brazil ($/MT)**

| Demand Region | Model Estimates | Actual Prices[1] | Absolute Deviation | Deviation (%) |
|---|---|---|---|---|
| Northeast | 217.09 | 189.63 | 27.46 | 14.48 |
| Center-North Goiás | 203.80 | 189.63 | 14.17 | 7.47 |
| SP, RJ, ES[2] | 209.86 | 213.81 | -3.95 | -1.85 |
| Santa Catarina | 221.78 | 213.81 | 7.97 | 3.73 |
| Southeast Paraná | 217.48 | 213.81 | 3.67 | 1.72 |
| East Rio Grande do Sul | 227.61 | 213.81 | 13.80 | 6.45 |
| North | 216.14 | 185.01 | 31.13 | 16.83 |
| Cuiabá, Mato Grosso | 187.73 | 178.91 | 8.82 | 4.93 |

[1] AMS/USDA (2007a). [2] São Paulo (SP), Rio de Janeiro (RJ), and Espírito Santo (ES).

In the case of the other exporting countries, the historical prices were obtained from different sources: the price for the United States is the unit value for 2006 from FAS/USDA (2007c). Canada was assumed to have the same export price as the United States. Argentina export price was sourced from FAS/USDA (2007d). Rest of South America's price was assumed to be the same as Argentina. Due to the lack of data and imprecision of shipping distance, the export price for India was also assumed to be equal to the CIF price of European Union (FAS/USDA, 2007d). As for the importing countries, the source for the China was from AMS/USDA (2007a) for 2006. EU CIF price was sourced from FAS/USDA (2007d) for 2005/06. Southeast Asia and the rest of the world were assumed to have the same CIF price as China and EU, respectively. Mexico is assumed to have the United States FOB price.

Table 21 presents the model-generated shadow prices and the historical data. Most of the model's shadow prices were within the range of less than five percent deviation. Only Mexico and India were overestimated and underestimated, respectively. However, the model estimates still matched the historical data from 2006 fairly well.

**Table 21. Comparison of Soybean Shadow Prices and Average Market Price at Different Exporting and Importing Countries ($/MT)**

| Exporting Country | Model Estimates | Actual Prices | Absolute Deviation | Deviation (%) |
|---|---|---|---|---|
| United States | 234.06 | 245.90 | -11.84 | -4.81 |
| Argentina | 234.14 | 227.00 | 7.14 | 3.15 |
| Rest of South America | 234.14 | 227.00 | 7.14 | 3.15 |
| Canada | 244.18 | 245.90 | -1.72 | -0.70 |
| India | 246.27 | 261.00 | -14.73 | -5.64 |
| **Importing Country** | **Model Estimates** | **Actual Prices** | **Absolute Deviation** | **Deviation (%)** |
| China | 278.94 | 279.00 | -0.06 | -0.02 |
| European Union | 271.05 | 261.00 | 10.05 | 3.85 |
| Southeast Asia | 278.94 | 279.00 | -0.06 | -0.02 |
| Mexico | 268.02 | 245.90 | 22.12 | 9.00 |
| Rest of the World | 267.77 | 261.00 | 6.77 | 2.59 |

*Source:* author's estimation.

# CHAPTER V

# EFFECTS OF TRANSPORTATION IMPROVEMENTS IN BRAZIL ON THE WORLD SOYBEAN MARKET

In this chapter, the economic impacts of transportation infrastructure in Brazil are analyzed. First, the separate effects of transportation improvements are evaluated vis-à-vis comparison between the most and least efficient in transportation costs reduction. Next, an analysis is performed by assuming that all transportation improvements are developed in Brazil at one time.

## Separate Effects of Transportation Improvements in Brazil

In this section, each transportation improvement is introduced into the base model and a comparison is done to evaluate each individual effect. In other words, the completion of the projected improvements is assumed to be functioning at its full efficiency in terms of transportation cost reduction. First, the effects on price and revenues by state in Brazil are evaluated by each proposed transportation improvement. Second, the average share of soybean exported by mode is analyzed and contrasted to the base model. Third, the improvements are expected to re-allocate soybean flows by port and, therefore, a comparison between the base and different scenarios will be made. Finally, an analysis of soybean exports, prices, and revenues is conducted for all exporting countries.

The effect of developing the Tapajós-Teles Pires waterway is relatively significant and has the largest impact of any single transportation improvement on prices and producer revenues (Table 22).

By constructing this waterway, the states which benefit the most are Mato Grosso and Rondônia (Table 22). In Mato Grosso, the soybean price and producer revenue increase by $12.28/MT and $347.95 million, respectively. For the state of Rondônia, the increase in price of $9.21/MT and revenue of $2.68 million is due to the conversion of the state from exporting through the Madeira-Amazon waterway to supplying the excess demand regions in the Northern Brazil. The model indicates that, as the supply regions in Mato Grosso increase exports due to lower transportation costs, the state of Rondônia will supply the local demand and no longer compete with Mato Grosso. As a result, Northern Brazil will experience a local price increase of $10.14/MT and revenue of $2.80 million. The average increase in soybean price and total increase in producer revenue are $2.98/MT and $339.11 million, respectively.

**Table 22. Model-Estimated Changes in Soybean Price ($/MT) and Producer Revenues (Millions $)**

| *Price* | Tapajós-Teles Pires | BR-163 Highway | Ferronorte (1) | Mortes-Araguaia | Ferronorte (2) | Ferropar |
|---|---|---|---|---|---|---|
| Bahia | -0.55 | -0.50 | -0.04 | -0.01 | -0.14 | -0.11 |
| Goiás | -0.55 | -0.50 | -0.04 | -0.01 | 2.24 | -0.11 |
| MA & PI(3) | -0.55 | -0.50 | -0.04 | -0.01 | -0.14 | -0.11 |
| MT(4) | 12.28 | 10.97 | 0.33 | 3.46 | -0.14 | -0.11 |
| MS(5) | -0.30 | -0.25 | -0.04 | -0.01 | -0.14 | 1.11 |
| MG(6) | -0.55 | -0.50 | -0.04 | -0.01 | -0.14 | -0.11 |
| North | 10.14 | 10.19 | -0.04 | -0.01 | -0.14 | -0.11 |
| Northeast | -0.55 | -0.50 | -0.04 | -0.01 | -0.14 | -0.11 |
| Paraná | -0.49 | -0.44 | 0.02 | -0.01 | -0.14 | -0.11 |
| RS(7) | -0.04 | 0.01 | -0.04 | -0.01 | -0.14 | 2.33 |
| Rondônia | 9.21 | 9.26 | -0.04 | -0.01 | -0.14 | -0.11 |
| SC(8) | 2.91 | 2.96 | 0.57 | -0.01 | -0.14 | -0.11 |
| Southeast | 0.78 | 0.83 | -0.04 | -0.01 | -0.14 | -0.11 |
| Tocantins | -0.55 | -0.50 | -0.04 | -0.01 | -0.14 | -0.11 |
| **Brazil** | **2.98** | **2.77** | **0.06** | **0.66** | **0.13** | **0.31** |
| *Revenues* | | | | | | |
| Bahia | -1.92 | -1.75 | -0.14 | -0.03 | -0.49 | -0.38 |
| Goiás | -5.40 | -4.91 | -0.39 | -0.10 | 55.20 | -1.08 |
| MA & PI | -1.15 | -1.04 | -0.08 | -0.02 | -0.29 | -0.23 |
| MT | 347.95 | 315.93 | 9.99 | 34.34 | -3.31 | -2.60 |
| MS | -0.60 | -0.34 | -0.21 | -0.05 | -0.72 | 10.14 |
| MG | -2.26 | -2.05 | -0.16 | -0.04 | -0.57 | -0.45 |
| North | 2.80 | 2.82 | -0.01 | 0.00 | -0.04 | -0.03 |
| Northeast | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Paraná | -7.35 | -6.63 | 0.01 | -0.14 | -2.02 | -1.59 |
| RS | 0.30 | 0.59 | -0.23 | -0.06 | -0.82 | 16.29 |
| Rondônia | 2.68 | 2.69 | -0.01 | 0.00 | -0.04 | -0.03 |
| SC | 2.66 | 2.71 | 0.52 | -0.01 | -0.13 | -0.10 |
| Southeast | 2.03 | 2.16 | -0.10 | -0.03 | -0.37 | -0.29 |
| Tocantins | -0.63 | -0.57 | -0.05 | -0.01 | -0.16 | -0.13 |
| **Brazil** | **339.11** | **309.60** | **9.13** | **33.84** | **46.24** | **19.52** |

(1) Rondonópolis. (2) Rio Verde. (3) Maranhão & Piauí. (4) Mato Grosso. (5) Mato Grosso do Sul. (6) Minas Gerais. (7) Rio Grande do Sul. (8) Santa Catarina.

Following the Tapajós-Teles Pires waterway, the next most significant improvement is the completion of the BR-163 highway (Table 22). Once again the states of Mato Grosso and Rondônia were the beneficiaries of this improvement. The price and revenues increases in Mato Grosso were $10.97/MT and $315.93 million, respectively. The state of Rondônia would experience a price increase of $9.26/MT and revenue increase of $2.69 million. Overall, completion of the BR-163 highway is projected to yield price and revenue gains to soybean producers of $2.77/MT and $309.60 million, respectively.

With respect to the development of the Mortes-Araguaia waterway, it was projected to yield gains for producers in Mato Grosso in both price ($3.46/MT) and revenues ($34.34 million). Such gains, however, come at the expense of other regions. They lose competitiveness and experience a reduction in price and revenue. Regarding nation-wide gains, the Ferronorte expansion from Rio Verde, Goiás, to a rail terminal located in Uberlândia, Minas Gerais, deserves more attention than other proposed railroad improvements. Such expansion would provide gains to the state of Goiás by increasing revenue by $55.20 million and price by $2.24/MT. However, only the state of Goiás benefits from this expansion and, consequently, the total soybean revenue and average price for Brazil would decrease by $46.24 million and $0.13/MT, respectively. Yet, such rail improvement still generates the largest effect on Brazil’s total soybean revenue and price.

As the improvements are integrated into the model, new average shares are expected. Now emphasis is focused on the changes in the average share of soybeans exported by mode due to new transportation improvements. Table 23 presents the changes resulting from these improvements in the modes of transportation. By introducing the Tapajós-Teles Pires waterway into the model, barge-mode participation in inland soybean transportation increased considerably from 12 percent in the base model to 44 percent. This increase is because most of the soybeans in the North of Mato Grosso were transported to the exporting ports (Santos and Paranaguá ports) by truck and with the new waterway soybeans are shipped by barge. In the case of the West of Mato Grosso, the soybeans originally shipped through the Madeira-Amazon waterway are now transported via the less costly Tapajós-Teles Pires waterway.

**Table 23. Model-Estimated Changes in Average Share of Soybean Exported by Transportation Mode in Different Improvements**

| Improvement | Truck | Rail | Barge |
|---|---|---|---|
| | | *Percentage (%)* | |
| Tapajós-Teles Pires | 31 | 25 | 44 |
| BR-163 Highway | 75 | 24 | 1 |
| Ferronorte (1) | 55 | 34 | 11 |
| Mortes-Araguaia | 55 | 28 | 17 |
| Ferronorte (2) | 52 | 37 | 11 |
| Ferropar | 60 | 28 | 11 |
| Base | 63 | 25 | 12 |

(1) Expansion to Rondonópolis.
(2) Expansion from Rio Verde to Uberlândia.

Upon the completion of the BR-163 highway, trucks are heavily used by Mato Grosso soybean producers, but, instead of transporting to Santos and Paranaguá ports in Southeast Brazil, the destination becomes Santarém port in the Amazon (Table 23). The

North and West regions of Mato Grosso ship 95 percent of their production by this new transportation route. Still, one percent of soybeans are shipped by barge from Rondônia through the Madeira-Amazon waterway. The Mortes-Araguaia waterway needs to be mentioned as this improvement increased the shipments via barge from the Northeast of Mato Grosso by five percent where previously soybeans were shipped by truck to the Paranaguá port in southeast Brazil.

Improvements related to railroad expansion had modest effects on altering the transportation use by mode (Table 23). The largest change is the Ferronorte expansion from Rio Verde, Goiás, to rail terminal located in Uberlândia, Minas Gerais. This expansion resulted in an increase in shipments by rail originated from the South of Goiás to Santos, where previously soybeans were shipped by truck to the same port. To be more precise, all exports from the leading producing regions of Goiás were transported by rail to the exporting port. With the expansion of the Ferronorte railroad to Rondonópolis, centroid[10] of the Southeast of Mato Grosso, such improvements increased the use of rail by nine percent when compared to the base model. In this case, soybeans were shipped through the Ferronorte railroad from Rondonópolis to the Santos port. Lastly, the expansion in the Ferropar railroad increases rail contribution by three percent, which is comparatively small when the other railroad expansion is taken into account.

As expected, changes in flows by ports in Brazil occurred (Table 24). With the development of the Tapajós-Teles Pires waterway and BR-163 highway, the Santarém port in the Amazon, which in the base model had no exports, becomes the leading

[10] Centroid is the city which represents the starting location for the route.

soybean exporter under both improvements, representing an increase in exports of 11.56 and 11.42 MMT, respectively. Most of the quantity exported through West and North of Mato Grosso took a different route, going north to Santarém instead of going southeast to the congested ports of Santos and Paranaguá. Additionally, the Itacoatiara port that is also located in the Amazon and linked by the Madeira-Amazon waterway, has a decrease in exports due to more efficient waterway (Tapajós-Teles Pires) and highway (BR-163). The Mortes-Araguaia waterway also reduces the quantity shipped to the congested port of Paranaguá. As Table 24 indicates, the Vila do Conde port located in Belém, in northern Brazil, is estimated to export 1.46 MMT, which originates from the Northeast of Mato Grosso state.

**Table 24. Model-Estimated Changes in Quantities of Soybeans from Selected Ports for the Base Model and Different Improvements (Thousand MT)**

| Port | Base Model | Tapajós-Teles Pires | BR-163 Highway | Ferronorte (1) | Mortes-Araguaia | Ferronorte (2) | Ferropar |
|---|---|---|---|---|---|---|---|
| Santos | 7906.46 | 2953.29 | 2953.50 | 9895.26 | 7906.35 | 7930.18 | 7905.29 |
| Paranaguá | 6166.74 | 3992.47 | 4129.88 | 5572.63 | 4701.10 | 6164.44 | 6183.91 |
| Itacoatiara | 3000.00 | 41.17 | 41.20 | 3000.00 | 3000.00 | 3000.00 | 3000.00 |
| Vitória | 2337.46 | 2336.10 | 2336.20 | 2337.37 | 2337.44 | 2337.12 | 2337.20 |
| Itaqui | 1895.81 | 1895.44 | 1895.48 | 1895.79 | 1895.81 | 1895.72 | 1895.74 |
| Santarém | 0.00 | 11562.59 | 11416.89 | 0.00 | 0.00 | 0.00 | 0.00 |
| Ilhéus | 1416.99 | 1416.66 | 1416.73 | 1417.38 | 1417.42 | 1417.24 | 1417.29 |
| São Francisco do Sul | 2500.00 | 1109.10 | 1109.30 | 1111.06 | 2500.00 | 2500.00 | 2500.00 |
| Rio grande | 899.73 | 899.70 | 899.71 | 899.73 | 899.73 | 899.72 | 899.73 |
| Vila do Conde | 0.00 | 0.00 | 0.00 | 0.00 | 1467.20 | 0.00 | 0.00 |
| **Brazil** | **26123.20** | **26206.52** | **26198.89** | **26129.22** | **26125.05** | **26144.42** | **26139.16** |

(1) Expansion to Rondonópolis. (2) Expansion from Rio Verde to Uberlândia.

In contrast, the improvements which involve railroad expansion generate an increase in flows to currently congested ports of Santos and Paranaguá. On the other hand, it would also reduce wear and tear on roads. For example, the extension of the Ferronorte to Rondonópolis, Southeast of Mato Grosso, increased exports from the Santos port by 1.98 MMT, which in the base model were shipped by truck to the Paranaguá and São Francisco do Sul ports (Table 24). The other Ferronorte expansion only increased the shipments from Goiás state to Santos port by 23 TMT. The exports from South of Goiás went to the same port, but by a different transportation mode (rail). Similarly, the Ferropar extension to Dourados, centroid of South of Mato Grosso do Sul, represented expanded rail shipments to Paranaguá.

Changes in exports, price, and revenue by countries are presented in table 25. As expected, the United States loses competitiveness as Brazil becomes more efficient in inland transportation. The only difference between the proposed improvements is the magnitude of changes in exports where the Tapajós-Teles Pires waterway had the greatest impact on the exports and the Mortes-Araguaia waterway had the lowest impact. In the case of the Mortes-Araguaia waterway, although the decrease in transportation costs is significant (about $11.00/MT, see table 10), the increase in exports is fairly modest due to the low soybean production in the affected region (Northeast of Mato Grosso). In addition, the completion of the BR-163 highway generates comparatively large gains as does the Ferronorte expansion to Rio Verde, Goiás.

**Table 25. Estimated Effects of Separate Transportation Improvements in Brazil on Exporting Countries Soybean Exports, Prices, and Revenue**

| Improvements | United States | Brazil | Argentina | RSA | Canada |
|---|---|---|---|---|---|
| Exports (1,000 MT) | | | | | |
| Tapajós-Teles Pires | -29.86 | 83.33 | -5.86 | -1.86 | -0.81 |
| BR-163 Highway | -27.11 | 75.70 | -5.29 | -1.69 | -0.74 |
| Ferronorte (1) | -2.01 | 6.03 | -0.40 | -0.12 | -0.05 |
| Mortes-Araguaia | -0.51 | 1.86 | -0.10 | -0.03 | -0.01 |
| Ferronorte (2) | -7.49 | 21.23 | -1.47 | -0.46 | -0.20 |
| Ferropar | -5.60 | 15.97 | -1.10 | -0.35 | -0.15 |
| Prices ($/MT) | | | | | |
| Tapajós-Teles Pires | -0.55 | 2.98 | -0.55 | -0.55 | -0.55 |
| BR-163 Highway | -0.50 | 2.77 | -0.50 | -0.50 | -0.50 |
| Ferronorte (1) | -0.04 | 0.06 | -0.04 | -0.04 | -0.04 |
| Mortes-Araguaia | -0.01 | 0.66 | -0.01 | -0.01 | -0.01 |
| Ferronorte (2) | -0.14 | 0.13 | -0.14 | -0.14 | -0.14 |
| Ferropar | -0.11 | 0.31 | -0.11 | -0.11 | -0.11 |
| Revenues (millions $) | | | | | |
| Tapajós-Teles Pires | -49.73 | 339.11 | -31.92 | -3.77 | -2.12 |
| BR-163 Highway | -45.21 | 309.60 | -29.02 | -3.43 | -1.92 |
| Ferronorte (1) | -3.62 | 9.13 | -2.32 | -0.27 | -0.15 |
| Mortes-Araguaia | -0.90 | 33.84 | -0.58 | -0.07 | -0.04 |
| Ferronorte (2) | -12.66 | 46.24 | -8.13 | -0.96 | -0.54 |
| Ferropar | -9.95 | 19.52 | -6.38 | -0.75 | -0.42 |

(1) Expansion to Rondonópolis. (2) Expansion from Rio Verde to Uberlândia.

With respect to prices and revenues, the largest impact was led by improvements in Brazil and development of the Tapajós-Teles Pires waterway. This waterway decreases price by $0.55/MT in the other exporting countries (Table 25). As for revenues, the effect on the United States is the largest due to its higher production level than other countries. Argentina's soybean producers see a decrease in their revenue by

$31.92 million. Among all the transportation improvements in Brazil, according to the model's estimates, the Ferronorte expansion to Rondonópolis has the slightest impacts on the price and revenues of the exporting countries.

## Combined Effects of Transportation Improvements in Brazil

In this analysis, the combined effects of Brazil's transportation improvements are incorporated into a single solution. In other words, it is assumed that all improvements will occur simultaneously.

Investigation of prices and revenues by state shows that Mato Grosso is the state with the most gains, followed by Goiás, Rio Grande do Sul, and Mato Grosso do Sul (Table 26). The impact on price for Mato Grosso is comparatively high (up $17.48/MT) due to the occurrence of four improvements in that state: development of the Tapajós-Teles Pires and Mortes-Araguaia waterways, the BR-163 highway, and the Ferronorte expansion to Rondonópolis. Among all four improvements, Tapajós-Teles Pires waterway has the greatest impact, followed by the BR-163 highway. In the state of Goiás, the Ferronorte expansion from Rio Verde to terminal in Uberlândia has the greatest impact on state's price and revenue. The soybean price for the state of Rio Grande do Sul increases by $3.93/MT because of an increase in the price in the excess demand region located in this state. Mato Grosso do Sul experienced an increase in both price and revenue because of the Ferropar expansion to Dourados.

**Table 26. Model-Estimated Changes in Soybean Price and Producer Revenues by State with Combined Improvements**

| State | Price ($/MT) |
|---|---:|
| Bahia | -1.16 |
| Goiás | 1.22 |
| Maranhão and Piauí | -1.16 |
| Mato Grosso | 17.48 |
| Mato Grosso do Sul | 1.39 |
| Minas Gerais | -1.16 |
| North | 9.53 |
| Northeast | -1.16 |
| Paraná | -1.10 |
| Rio Grande do Sul | 3.93 |
| Rondônia | 8.60 |
| Santa Catarina | 2.30 |
| Southeast | 7.05 |
| Tocantins | -1.16 |
| **Brazil** | **4.82** |
| State | Revenues (millions $) |
| Bahia | -4.05 |
| Goiás | 45.18 |
| Maranhão and Piauí | -2.42 |
| Mato Grosso | 414.58 |
| Mato Grosso do Sul | 16.38 |
| Minas Gerais | -4.76 |
| North | 2.64 |
| Northeast | 0.00 |
| Paraná | -16.17 |
| Rio Grande do Sul | 28.57 |
| Rondônia | 2.50 |
| Santa Catarina | 2.11 |
| Southeast | 18.39 |
| Tocantins | -1.32 |
| **Brazil** | **501.61** |

Since the state of Paraná does not improve its transportation network, the decrease of $1.10/MT generated by other region's improved competitiveness causes a reduction in producer revenue of $16 million (Table 26). Other producing states of Bahia, Maranhão and Piauí, and Minas Gerais, experience decline in revenue as well. The state of Rondônia is an exception because the crop is no longer exported but is shipped to an excess demand location in Brazil, which indicates less expenditure on transportation and, therefore, a higher price paid to producers.

As indicated in the previous section, the share of transportation mode with combined improvements is compared to the base model. The transportation share by mode becomes more evenly distributed (Table 27). However, the most expensive transportation mode, truck, still dominates with 41 percent, 22 percentage points lower from the base model. The reason for such high truck participation is BR-163 highway which accounts for 59 percent (6.43 MMT) of the total soybean transported by truck (10.82 MMT) in Brazil.

**Table 27. Model-Estimated Changes in Average Share of Soybean Exported by Transportation Mode in Different Improvements**

| Mode | Base Model | Combined Improvements |
|---|---|---|
| | *Percentage (%)* | |
| Truck | 63 | 41 |
| Rail | 25 | 34 |
| Barge | 12 | 25 |

Barge and rail transportation increase by 13 and 9 percentage points, respectively. The major contributor to barge transportation is the Tapajós-Teles Pires waterway, accounting for 77 percent (5.01 MMT) of the total soybean shipped by barges (6.52 MMT) to exporting ports. The remaining 23 percent is hauled by the Mortes-Araguaia and Madeira-Amazon waterways. Additionally, the Madeira-Amazon waterway becomes an insignificant exporting route shipping only 0.04 MMT compared to 3.0 MMT in the base model.

Regarding rail transportation, the Ferronorte expansion from Rio Verde to the terminal at Uberlândia together with the Ferropar expansion to Dourados represents 59 percent (5.32 MMT) of all soybeans carried by trains (8.94 MMT) to exporting ports. However, the Ferronorte expansion to Rondonópolis, which would reduce transportation costs for the Southeast of Mato Grosso, does not transport soybeans to exporting ports. Soybeans from the Southeast of Mato Grosso are sent to be crushed in the excess demand region located in Cuiabá.

Similar to the case of separate improvements, the soybean flows to exporting ports in Brazil are examined and compared with the base model. Table 28 indicates the changes generated by the combined improvements. Once again the Santarém port, which is located in the North of Brazil and connected through the Tapajós-Teles Pires waterway and BR-163 highway, becomes the top soybean port. Exports through this port are estimated to represent 44 percent of Brazil’s soybean exports. The newly generated soybean flows are evenly distributed through other ports. For example, Santos and Paranaguá accounted for approximately 12 percent each and Vitória nine percent. The other minor ports of Itaqui, Ilhéus, and Vila do Conde represent 7.2, 5.3, and 5.5 percent, respectively. Itacoatiara port becomes the lowest soybean exporter because of the new routes connecting North and West of Mato Grosso to Santarém.

**Table 28. Model-Estimated Changes in Quantities of Soybeans from Selected Ports for the Base Model and Combined Improvements (Thousand MT)**

| Port | Base Model | Combined Improvements |
|---|---|---|
| Santos | 7906.46 | 2975.95 |
| Paranaguá | 6166.74 | 2713.67 |
| Itacoatiara | 3000.00 | 40.88 |
| Vitória | 2337.46 | 2334.49 |
| Itaqui | 1895.81 | 1895.03 |
| Santarém | 0.00 | 11451.21 |
| Ilhéus | 1416.99 | 1415.78 |
| São Francisco do Sul | 2500 | 1106.72 |
| Rio Grande | 899.73 | 899.68 |
| Vila do Conde | 0.00 | 1467.08 |
| **Brazil** | **26123.19** | **26300.49** |

After analyzing the price, revenue, transportation mode shares, and flows by exporting ports in Brazil, the impact of the transportation improvements in Brazil on competitiveness of exporting countries is evaluated with the focus on exports, prices, and revenue.

Table 29 presents the impacts of these improvements in transportation. The United States, Argentina, Rest of South America, and Canada all experience lower exports, prices, and revenue. Among these countries, the United States is the most affected by the improvement of Brazil’s transportation efficiency. Exports, price, and revenue in the United States are estimated to decrease by 63.73 TMT, $1.16/MT, and

$104.89 million, respectively. Meanwhile, the losses to other exporting countries are lower than those of the United States.

**Table 29. Estimated Effects of Combined Transportation Improvements in Brazil on Exporting Countries Soybean Exports, Prices, and Revenue**

| Exports (1,000 MT) | Combined Improvements |
|---|---|
| United States | -63.73 |
| Brazil | 177.30 |
| Argentina | -12.50 |
| Rest of South America | -3.97 |
| Canada | -1.74 |
| Prices ($/MT) | |
| United States | -1.16 |
| Brazil | 4.82 |
| Argentina | -1.16 |
| Rest of South America | -1.16 |
| Canada | -1.16 |
| Revenues (millions $) | |
| United States | -104.89 |
| Brazil | 501.61 |
| Argentina | -67.33 |
| Rest of South America | -7.95 |
| Canada | -4.46 |

By reducing transportation costs, Brazil gains competitiveness through increases in exports, prices, and revenue (Table 29). The increase in exports is equal to 177.3 TMT and due to less costly transportation routes such as the Tapajós-Teles Pires waterway and the BR-163 highway. These two improvements lead to an increase in soybean price for the state of Mato Grosso by $17.48/MT and the revenue by $414 million, which accounts for 83 percent of Brazil's total increase in revenue ($501 million).

In summary, although all proposed improvements have individual impacts on Brazil and on the world soybean market, some specific improvements larger effects than others. The development of the Tapajós-Teles Pires waterway and the completion of the BR-163 highway fit into that category. On the other hand, the improvements related to railroad expansion have a smaller impact as in the case of the Ferronorte expansion to Rondonópolis. As expected, the combined improvements scenario indicates greater impacts than the separate scenario on Brazil and the world soybean market.

# CHAPTER VI

## SUMMARY AND CONCLUSIONS

The lack of adequate transportation infrastructure in Brazil is commonly discussed among local soybean producers. For the majority of the soybean producers in Brazil, the transportation network lags the soybean production expansion. Some observers believe it will collapse in the near future. According to some representatives of the soybean industry in Brazil, proposed transportation improvements are not expected to occur in the next 30 years. As was discussed in chapter I, Brazil's transportation costs are higher than those in the United States and reduce the competitiveness in terms of total delivered costs to export destinations. In the leading soybean producing state, Mato Grosso, soybeans are transported 2,000 kms by truck, incurring an additional average inland transportation cost of $1.80/MT, $1.32/MT higher than a comparable distance for United States.

Therefore, transportation improvements are expected to enhance Brazil's competitiveness and generate significant gains to local producers. On the other hand, the United States, Argentina, and other exporting countries experience losses due to lower export share and decreases in price. The following are the improvements examined in this study: (i) the development of the Tapajós-Teles Pires waterway; (ii) the completion of the BR-163 highway; (iii) the construction of the Mortes-Araguaia waterway; (iv) Ferronorte extension to Rondonópolis, Mato Grosso; (v) Ferronorte expansion linking

Rio Verde, Goiás, to rail terminal at Uberlândia, Minas Gerais; and (vi) Ferropar expansion to Dourados, Mato Grosso do Sul.

To analyze possible improvements, first the reductions in transportation costs for each improvement were estimated. Then, a spatial equilibrium model was developed to specify the base soybean transportation network in Brazil and international trade. Validation was completed for the base model to evaluate its predictive power. Once the model validation procedure was performed, various improvements in Brazil's transportation network were incorporated into the base model. These improvements were analyzed separately and all together. The separate analysis focused on quantifying changes in the base model generated by each individual improvement holding other improvements constant. As for the combined effect, analysis assumed that all improvements occur simultaneously and took into account the combined impact.

The separate effects of improvements in transportation infrastructure were consistent with cases of reduction in transportation costs. In other words, if an exporting country (Brazil) decreases transportation costs, prices, revenues, and exports will increase. On the other hand, the same variables for the competing exporting countries will decline. In addition, the country with the improved transportation network will affect the transportation share by mode and flows to ports.

For example, the development of the Tapajós-Teles Pires waterway would reduce transportation costs by nearly $11.65/MT. This improvement represents an increase in price, revenue, and exports of $2.98/MT, $339.11 million, and 83 thousand MT, respectively. Regarding transportation share by mode, barge transportation increased its share from 12 to 44 percent. The newly developed waterway helps the Santarém port to become the leading soybean exporting port with 11.56 MMT in exports. Among other exporting countries, the United States experiences a decrease in price, revenue and exports of $0.55/MT, $49.73 million, 29.86 thousand MT, respectively. Similarly, Argentina, Rest of South America, and Canada also have a decrease in price, revenue, and exports.

However, such gains for Brazil and losses for the competing exporting countries are modest in relative value. The percentage increase for Brazil in price, revenue, and exports is 1.48, 2.35, and 0.32 percent, respectively. For the United States, the relative loss in price, revenue, and exports is equal to 0.23, 0.23, and 0.12 percent, respectively. For Argentina, the relative decrease in price, revenue, and exports is 0.23, 0.24, and 0.01 percent, respectively. The decrease in relative value for price, revenue, and exports is less than 0.01 percent for the Rest of South America and Canada.

The second most important improvement to Brazil's competitiveness is the BR-163 highway. Upon completion of this highway, the price, revenue, and exports increase by $2.77/MT, $309.60 million, and 75.70 thousand MT, respectively. As soon as the BR-163 highway becomes an efficient exporting route, truck transportation will represent 75 percent of average soybean exported, a 12 percentage point increase compared to the base model. The BR-163 highway further reinforces the position of the Santarém port as a top soybean exporting port. Similarly, the United States and other exporting countries experience a decrease in price, revenue, and exports.

Improvements in the BR-163 highway has modest relative effects on price, revenue, and exports in Brazil and in the competing exporting countries as well. In relative terms, the increase in soybean price, revenue, and exports for Brazil is 1.38, 2.14, and 0.29 percent, respectively. For the United States, the relative drop in price, revenue, and exports is 0.21, 0.21, and 0.11 percent, respectively. As for Argentina, the relative decrease in price, revenue, and exports are equal to the United States except for exports (0.07 percent). The decrease in relative value for price, revenue, and exports is less than 0.01 percent for the Rest of South America and Canada.

From the analysis of separate improvements, it is important to note the small potential impact of railroad improvements on the soybean market in Brazil and other countries. The only railroad expansion that has a major impact is the Ferronorte expansion from Rio Verde to the terminal at Uberlândia, Minas Gerais. This expansion generates an increase in price and revenue for Brazil of $0.13/MT and $46.24 million, respectively. In addition, exports increase by 21.23 thousand MT. Regarding the transportation share by mode, rail transportation increases by nine percent and truck decreases by eight percent. With respect to flows by port, Santos reinforces its lead as the top soybean export port with 9.89 MMT exports compared to 7.90 MMT in the base model. The competing countries become less competitive in the world soybean market, but the decrease in prices, revenue, and exports is smaller than that in the two previously discussed improvements. If the relative changes for price, revenue, and exports are modest for the Tapajós-Teles Pires waterway and BR-163 highway, a much lower impact is expected for the railroad improvement.

The scenario of combined effects of transportation improvements in Brazil incorporates all improvements into the base model and the results are compared between pre-improvements to post-improvements.

In this scenario, the price and revenue increases considerably when compared to individual transportation improvement. The increase in price and revenue are $4.82/MT and $501.61 million, respectively. The transportation share by mode becomes more equally distributed with increased utilization of waterways and railroads and less reliance on truck. As a result, Santarém becomes the leading export port for soybeans originating in North and West Mato Grosso. The leading exporting ports of Santos and Paranaguá in the base model now rank second and third, respectively. Changes in the international soybean market are larger when compared to separate improvements as the United States, Argentina, Rest of South America, and Canada lose competitiveness.

The results again show that the most important improvements are the development of the Tapajós-Teles Pires waterway and the completion of the BR-163 highway. These improvements not only have the highest contribution to price and revenue increases, but also change the transportation share by mode and soybean flows by port. In the state of Mato Grosso alone, where both improvements are assumed to occur, the increase in price and revenue is $17.48 and $414.58 million, respectively. According to the results, this is the largest state increase. As for transportation share by mode, the BR-163 highway is the main factor for maintaining truck as the main mode (trucks are responsible for 41 percent of soybeans transported to ports). The Tapajós-Teles Pires becomes the most important waterway in Brazil followed by the Mortes-

Araguaia waterway, both of which account for almost the total barge share (the Madeira-Amazon waterway still exports 40 thousand MT). Overall, the main exporting routes are the BR-163 highway and the Tapajós-Teles Pires waterway. These new routes transport 44 percent of total soybean exports.

In the case of separate scenarios, the railroad improvements have comparatively small impacts on the soybean market in Brazil. The highest increase in price generated by a railroad improvement is $1.22/MT for the state of Goiás by the Ferronorte expansion from Rio Verde to the terminal in Uberlândia. By excluding Mato Grosso, the total revenue gain generated by railroad improvements for the affected states (Goiás and Mato Grosso do Sul) is $61.57 million.  It is noteworthy that the transportation share of rail increased by nine percentage points (from 25 percent to 34 percent).

By assessing the relative effects, the changes in the combined analysis are greater than the separate improvements. In Brazil, the relative increase in price and revenue are 2.41 and 3.48 percent, respectively. However, the total quantity exported by Brazil only increase by 0.67 percent, which is moderate compared to the gains in price and revenue. For the United States, the relative decrease in both price and revenue is 0.50 percent. Only a 0.25 percent decrease is predicted for exports. The same occurs in Argentina, Rest of South America, and Canada. The decrease in price, revenue, and exports for these countries were below 0.50, 0.50, and 0.17 percent, respectively.

Results from the separate and combined improvements indicate that Brazil’s share of the world soybean market is altered by less than one percent. However, these results should be considered as the minimum change since the soybean quadratic mathematical model only represents short-run excess supply and demand behavior. If this takes place in the long run, the reduction in transportation costs would increase Brazil's competitiveness in the global market as producers and consumers gradually adjust to the new transportation infrastructure.

It is also important to mention the large impact of certain improvements. For example, the Tapajós-Teles Pires waterway and the BR-163 highway were estimated to generate more gains than any other railroad improvements. In the latest Brazilian government investment plan (PAC – 2007/10), the completion of the BR-163 highway, the Mortes-Araguaia waterway, and the Ferronorte extension to Rondonópolis were expected to be funded. However, the other improvements were not noted in this new investment plan.

For future research, the model could be improved, more realistic, and precise with further division of the excess supply and demand regions in Brazil. In addition, more detailed specification on importing countries would also assist to better assess international trade flows. Development of a new model containing production, consumption, exports and imports for the long-run would also be more appropriate and applicable vis-à-vis the effects of Brazil's current infrastructure improvements on the world soybean market.

# REFERENCES

Anania, G., and A.F. McCalla. 1991. “Does Arbitrating Matter? Spatial Trade Models and Discriminatory Trade Policies.” *American Journal of Agricultural Economics* 73:103-17.

Associação Brasileira das Indústrias de Óleos Vegetais (ABIOVE), 2007. *Capacidade Instalada da Indústria de Óleos Vegetais*. São Paulo, Brazil. Available at http://www.abiove.com.br/capacidade_br.html, accessed March, 2007.

Associacao Nacional dos Usuarios de Transporte de Cargas (ANUT), 2004. *Transporte – Desafio ao Crescimento do Agronegocio Brasileiro.* Rio de Janeiro, Brazil. Available at http://www.anut.org.br/estudos_trabalhos.asp, accessed April, 2007.

Central Intelligende Agency (CIA), 2007. *The World Factbook*. Office of Public and Agency Information, Washington, D.C. 20505. Available at https://www.cia.gov/library/publications/the-world-factbook/, accessed March, 2007.

Centro de Estudos Avançados em Economia Aplicada (CEPEA), 2007. *PIB do Agronegócio.* São Paulo, Brazil. Available at http://www.cepea.esalq.usp.br/pib/, accessed March, 2007.

Costa, R.F., C.P. Rosson, III, and E.F. Costa. 2007. “Decreasing Brazil’s Transportation Costs Through Improvement in Infrastructure: A General Equilibrium Analysis on the Soybean Complex World Market.” *Journal of Food Distribution Research* 38(1): 28-35.

Cramer, G.L., E.J. Wailes, and S. Shui, 1993. “Impacts of Liberalizing Trade in the World Rice Market.” *American Journal of Agricultural Economics* 75(1):219-26.

Devadoss, S., A.H. Aguiar, S.R. Shook, and J. Araji, 2005. “A Spatial Equilibrium Analysis of U.S.-Canadian Disputes on the World Softwood Lumber Market.” *Canadian Journal of Agricultural Economics* 53:177-92.

Enke, S., 1951. “Equilibrium Among Spatially Separated Markets: Solution by Electric Analogue.” *Econometrica* 19:40-47.

Fellin, L. 1993. “International Corn and Soybean Transportation System: Quadratic Programming Models.” PhD Dissertation, Department of Agricultural Economics, Texas A&M University, College Station.

Fellin, L. and S.W. Fuller, 1998. "Privatization of Mexico's Railroad System and Implications for U.S./Mexico Grain/Oilseed Trade." Texas A&M University, Department of Agricultural Economics, Texas Agricultural Market Research Center Report IM 1-98, January.

Flaskerud, G., 2003. "Brazil's Soybean Production and Impact." North Dakota State University Extension Service, Number EB-79, July.

Food and Agricultural Policy Research Institute (FAPRI), 2007. *Elasticities Database*. Ames, Iowa State University. Available at http://www.fapri.org/tools/elasticity.aspx, accessed April, 2007.

Fuller, S.W., L. Fellin, and W. Grant, 1998. "The Upper Mississippi/Illinois Rivers and Grain/Soybean Transportation: An Analysis of Transportation Capacities." Texas A&M University, Department of Agricultural Economics, Texas Agricultural Market Research Center Report CM 1-98, January.

Fuller, S.W., L. Fellin, and K. Eriksen, 2000 "Panama Canal: How Critical to U.S. Grain Exports." *Agribusiness: An International Journal* 16(4):435-57.

Fuller, S.W., T.H. Yu, L. Fellin, A. Lalor, and R. Krajewski, 2001. "Effects of Improving Transportation Infrastructure on Competitiveness in World Grain Markets." *Journal of International Food & Agribusiness Marketing* 13(4):61-85.

Fuller, S.W., L. Fellin, and V. Salin, 2003. "Effect of Liberalized U.S.-Mexico Rice Trade: A Spatial, Multiproduct Equilibrium Analysis." *Agribusiness* 19(1):1-17.

Kalaitzandonakes, N., 2006. "Cartagena Protocol: A New Trade Barrier?" *Regulation* 29 (2):18-25, Summer 2006.

Martins, R.S. and M.B. Lemos, 2006. "Corredor Centro-Leste: Sistemas de Transporte de Minas Gerais na Perspectiva dos Eixos de Desenvolvimento e Integração." Texto para Discussão, No. 289, Universidade Federal de Minas Gerais, Brazil, May.

McCarl, B.A., and T.H. Spreen, 2003. "Applied Mathematical Programming Using Algebraic Systems." Unpublished, Texas A&M University.

Meyers, W.H, S. Devadoss, and M. Helmar, 1991. "The World Soybean Trade Model: Specification, Estimation, and Validation." Techinical Report 91-TR23, CARD, Ames, Iowa State University, September.

Ministério da Agricultura, Pecuária e Abastecimento, Companhia Nacional de Abastecimento (CONAB/MAPA), 2007a. *Safras – Grãos*. Brasília, Brazil. Available at http://www.conab.gov.br/conabweb/, accessed March, 2007.

Ministério da Agricultura, Pecuária e Abastecimento, Companhia Nacional de Abastecimento (CONAB/MAPA), 2007b. *Balança Comercial do Agronegócio.* Brasília, Brazil. Available at http://www.conab.gov.br/conabweb/, accessed March, 2007.

Ministério da Agricultura, Pecuária e Abastecimento, Companhia Nacional de Abastecimento (CONAB/MAPA), 2007c. *Corredores de Escoamento da Produção Agrícola.*. Brasília, Brazil. Available at http://www.conab.gov.br/conabweb/, accessed April, 2007.

Ministério do Desenvolvimento, Indústria e Comércio Exterior, Secretária de Comércio Exterior (SECEX/MDIC), 2007. *Aliceweb*. Brasília, Brazil. Available at http://aliceweb.desenvolvimento.gov.br/default.asp, accessed March, 2007.

Ministério do Planejamento, Orçamento e Gestão, Instituto Brasileiro de Geografia e Estástica (IBGE/MPOG), 2007. *Produção Agrícola Municipal – PAM*. Brasília, Brazil. Available at http://www.ibge.gov.br/home/estatistica/economia/pam/, accessed May, 2007.

Ministério dos Transportes (MT), 2007a. *Mapas e Informações*. Brasília, Brazil. Available at http://www.transportes.gov.br/, accessed May, 2007.

Ministério dos Transportes, Departamento Nacional de Infra-Estrutura de Transportes (DNIT/MT), 2007b. *Programa de Aceleração do Crescimento*. Brasília, Brazil. Available at http://www.dnit.gov.br/menu/pac/pac_inicio, accessed April, 2007.

Ministério dos Transportes, Empresa Brasileira de Planejamento de Transportes (GEIPOT/MT), 2001. *Corredores Estratégicos de Desnevolvimento: Alternativas de Escoamento de Soja para Exportação.* Brasília, Brazil. Available at http://www.transportes.gov.br/bit/estudos/interligacoes/sumario.htm, accessed April, 2007.

Mueller, C.C. 2003. "Expansion and Modernization of Agriculture in the Cerrado – the Case of Soybeans in Brazil's Center-West." Série Textos para Discussão, Departamento de Economia, No. 308, Universida de Brasília, Brazil, November.

Normali, A., 2007. Companhia das Docas do Estado da Bahia (CODEBA). Salvador, Bahia, Brazil. Personal email communication on August 21, 2007.

Olowolayemo, S., 2007. U.S. Department of Agriculture, Agricultural Marketing Service (AMS/USDA). Washington D.C. Personal email communication on May 2nd, 2007.

Piggott, N.E. and M.K. Wohlgenant, 2002. "Price Elasticities, Joint Products, and International Trade." *The Australian Journal of Agricultural and Resource Economics* 46:487-500.

Sampaio, L.M.B. 2004. "A Competitividade Brasileira no Mercado Internacional de Soja." PhD dissertation, Departamento de Economia, Universidade Federal de Pernambuco, Recife, Brazil.

Samuelson, P.A. 1952. "Spatial Price Equilibrium and Linear Programming." *American Economic Review* 42(1):283-303.

Schnepf, R.D., E. Dohlman, and C. Bolling. 2001. *Agriculture in Brazil and Argentina: Developments and Prospects for Major Field Crops.* Washington D.C.: Department of Agriculture, Economic Research Service, Agriculture and Trade Report, WRS-01-3, December.

Shei, S. and R.L. Thompson, 1977. "The Impacts of Trade Restrictions on Price Stability in the World Wheat Market." *American Journal of Agricultural Economics* 59:628-38.

Sistema de Informações de Fretes (SIFRECA), 2007. Piracicaba, São Paulo, Brazil. Available at http://sifreca.esalq.usp.br/sifreca/pt/index.php, accessed May, 2007.

Takayama, T. and G.G. Judge, 1971. *Spatial and Temporal Price and Allocation Models.* Amsterdam, North Holland Publishing Co.

U.S. Department of Agriculture, Agricultural Marketing Service (AMS/USDA), 2007a. *Brazil Soybean Transportation*. Washington D.C. Available at www.ams.usda.gov/tmdtsb/grain, accessed March, 2007.

U.S. Department of Agriculture, Economic Research Service (ERS/USDA), 2007. *International Macroeconomic Datasets.* Washington D.C. Available at http://www.ers.usda.gov/data/macroeconomics/, accessed February, 2007.

U.S. Department of Agriculture, Foreign Agriculture Service (FAS/USDA), 2005. *GAIN Report.* Report Number: BR5631. Washington D.C. Available at http://www.fas.usda.gov/, accessed April, 2007.

U.S. Department of Agriculture, Foreign Agriculture Service (FAS/USDA), 2007a. *Production, Supply, and Demand (PS&D) online database.* Washington D.C. Available at http://www.fas.suda.gov/psd/, accessed January, 2007.

U.S. Department of Agriculture, Foreign Agriculture Service (FAS/USDA), 2007b. *GAIN Report*. Report Number: BR7618. Washington D.C. Available at http://www.fas.usda.gov/, accessed March, 2007.

U.S. Department of Agriculture, Foreign Agriculture Service (FAS/USDA), 2007c. *Fatus - Commodity Aggregations.* Washington D.C. Available at http://www.fas.usda.gov/ustrade/, accessed April, 2007.

U.S. Department of Agriculture, Foreign Agriculture Service (FAS/USDA), 2007d. *Oilseeds: World Markets and Trade.* Circular Series, January 1st, Washington D.C. Available at http://www.fas.usda.gov/, accessed May, 2007.

Waquil, P.D. and T.L. Cox, 1995. "Spatial Equilibrium with Intermediate Products: Implementation and Validation in the MERCOSUR." Staff Paper Series No. 388, Department of Agricultural Economics, University of Wisconsin-Madison, December.

Wilson, W.W. and W.W. Koo, 1985. "Grain Transportation Rates and Export Market Development." *North Central Journal of Agricultural Economics* 7(1):27-39.

Yu, T.H., J. Zhang, and S.W. Fuller. "Freight Transportation Demands on the Upper Mississippi and Illinois Rivers." *Journal of the Transportation Research Forum* 45 (2).

# APPENDIX A

## MAPS OF RAILROADS, WATERWAYS, AND PORTS IN BRAZIL


**Figure A1. Map of ports in Brazil**
*Source*: Ministério dos Transportes (MT) (2007a).

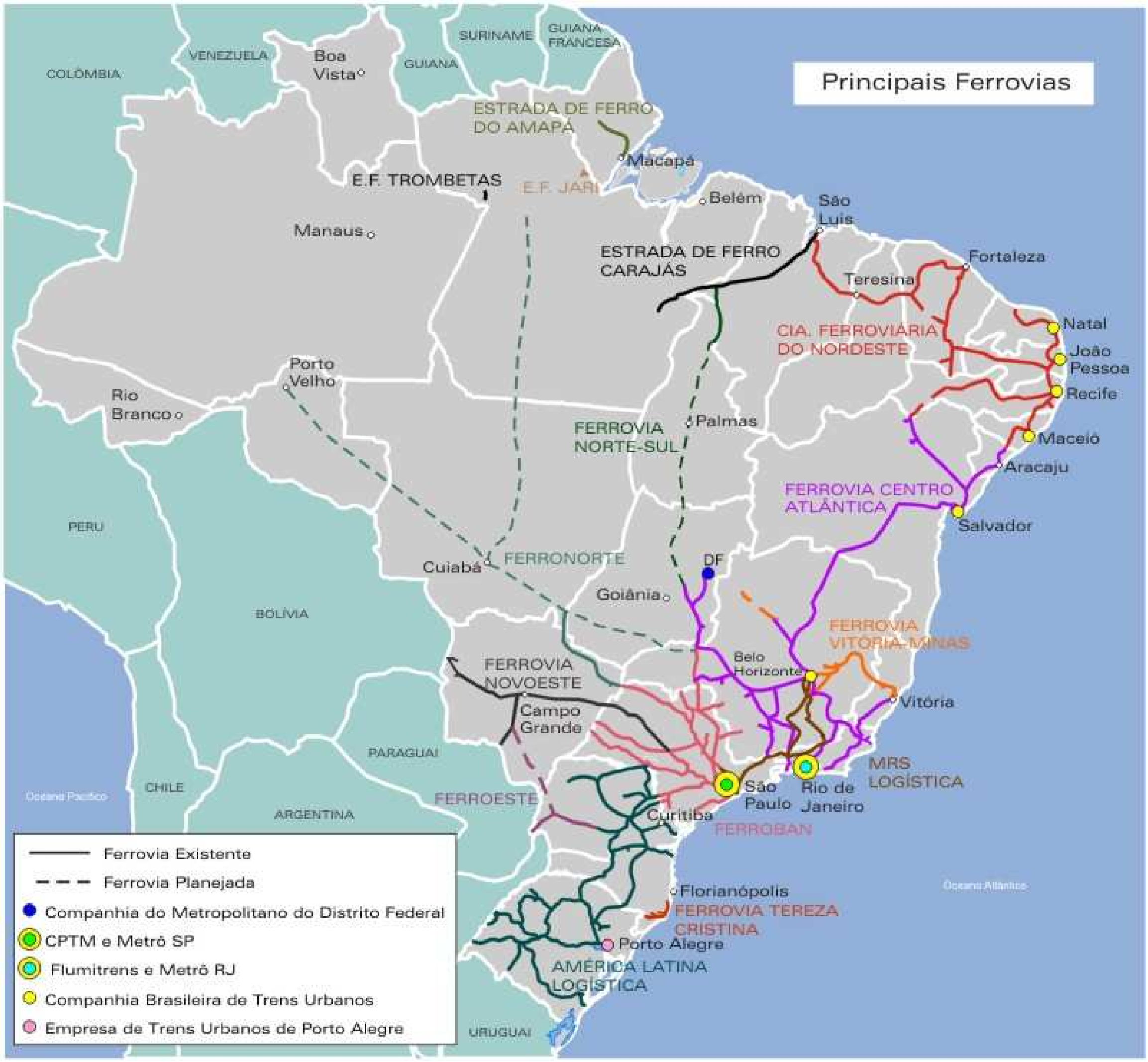


**Figure A2. Map of railroads in Brazil**
*Source*: MT (2007a).

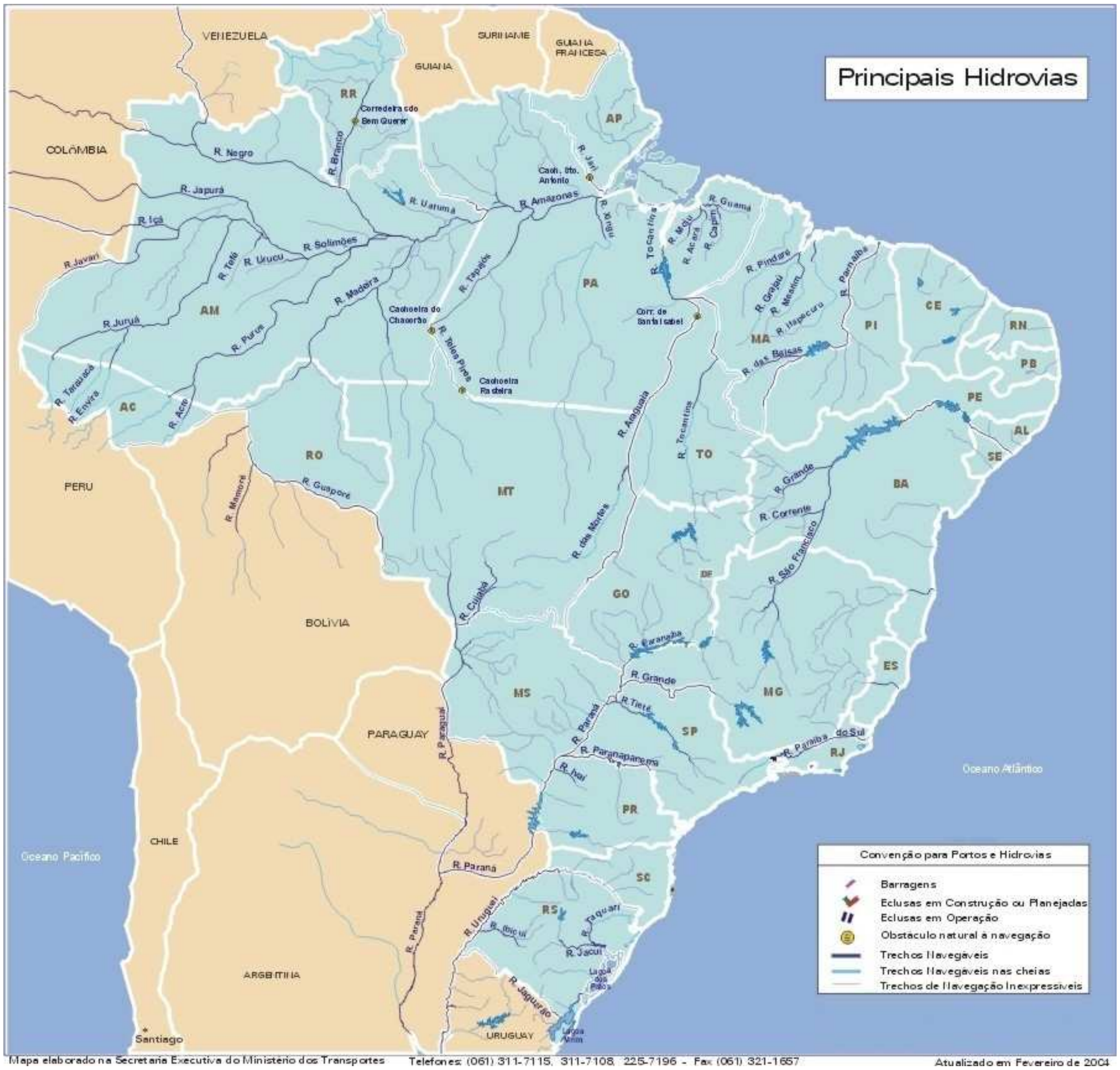


**Figure A3. Map of waterways in Brazil**
*Source*: MT (2007a).

# APPENDIX B

## ESTIMATION OF ELASTICITY OF TOTAL DEMAND FOR SOYBEANS IN BRAZIL

To estimate the elasticity of total demand for soybeans in Brazil, first the average soybean disappearance for Brazil during the period 1990-2005 was calculated to be ($s^d$ = 0.7787). The average Brazilian soybean, soymeal, and soyoil export prices for the same period were 224.43 \$/MT ($P_b$), 191.53 \$/MT ($P_m$), and 466.12 \$/MT ($P_o$), respectively. Based on Piggott and Wohlgenant (2002) calculation for yields in the United States, the soymeal ($\alpha$) and soyoil ($\beta$) yields were 0.792 and 0.178, respectively. The elasticities of meal ($\eta_m$) and oil ($\eta_o$) demand for Brazil were -0.06 and -0.05, respectively (Meyers et al, 1991).

As for the elasticity of export demand for soybeans for Brazil ($\eta_{xb}$), the following equation was developed (Piggott and Wohlgenant, 2002):

$$BRExp_t = f(CIFPrice_t, WGDPCap_t, BRExp_{t-1})$$

where $BRExp_t$ is soybean exports by Brazil, $CIFPrice_t$ is Rotterdam real CIF price, $WGDPCap_t$ is the average world GDP per capita, and $BRExp_{t-1}$ is the lag soybean exports by Brazil. By taking the natural logarithm (ln) of both sides of the above equation, it gives

$$\ln(BRExp_t) = \alpha_0 + \alpha_1 \ln(CIFPrice_t) + \alpha_2 \ln(WGDPCap_t) + \alpha_3 \ln(BRExp_{t-1}) + \varepsilon_t$$

where $\alpha_0$ is the intercept and $\varepsilon_t$ is the residual term. The elasticity of export demand for soybeans ($\eta_{xb}$) was obtained from the estimated coefficients on the lag price variable

($\alpha_1$). The signs on the coefficients for all variables were as expected. The coefficient for the price variable was significant at the 0.10 level. Adjusted R-squares for the equation was 0.9241. The Durbin-Watson test (D-W) was 1.9979 which can be considered inconclusive regarding positive, first order correlations. The estimated elasticity of export demand for soybeans was -0.9087. All the data were from FAS/USDA (2007d) except the world GDP per capita which was sourced from ERS/USDA (2007).

Last, the following linear equation was used to estimate the elasticity of price transmission ($\varepsilon_{fb}$):

$$CIFPrice_t = f(FOBPrice_t)$$

where $CIFPrice_t$ is the Rotterdam real CIF price and $FOBPrice_t$ is Brazil real export price. By using price data from FAS/USDA (2007d) over the period 1990-2005 and taking the natural logarithm (ln), the following linear regression was estimated:

$$\ln(CIFPrice_t) = 1.359 + 0.77 \ln(FOBPrice_t)$$

where 0.77 was the elasticity of price transmission for soybeans. The coefficient for the variable $FOBPrice_t$ was significant at the 0.01 level. Adjusted R-squares for the equation was 0.6582.

# VITA

**Rafael de Farias Costa**
203 Spruce St. Apt. A, College Station, TX 77840 Ph: (979) 845-7221
E-mail: rfcosta@ag.tamu.edu

**EDUCATION**

- Texas A&M University, College Station, TX, Ph.D., Agricultural Economics. In progress.
- Texas A&M University, College Station, TX, M.S., Agricultural Economics. August, 2005 – December, 2007.
- Federal University of Pernambuco (UFPE), Brazil, B.S., Economics. April, 2002 – April, 2005.

**FIELDS OF SPECIALIZATION AND RESEARCH INTEREST**

- International Agricultural Trade and Transportation Economics.

**PUBLICATIONS**

- **Costa, Rafael F.**, C.P. Rosson III, Ecio F. Costa. "*Decreasing Brazil's Transportation Costs through Improvement in Infrastructure: A General Equilibrium Analysis on the Soybean Complex World Market.*" Journal of Food Distribution Research, 38(1): 28-35. (Proceedings).
- Xavier, Leonardo F., **Rafael F. Costa**, and Ecio F. Costa. "*The Adoption of Water Saving Technologies on Fruit Irrigation in the Sao Francisco Valley: A Comparison between Small and Large Farmers' Perceptions*". (In Portuguese). Revista de Economia e Sociologia Rural, vol. 44, p. 267-292, 2006.

**PAPERS FOR PRESENTATION (three most important)**

- **Rafael F. Costa** and C. Parr Rosson, III. "*Improving Transportation Infrastructure in Brazil: An Analysis Using Spatial Equilibrium Model on the World Soybean Market.*" Paper presented at the American Agricultural Economics Association (AAEA) Meeting, July 29 – August 1, 2007, Portland, Oregon.
- **Rafael F. Costa**, Xia Yan, and C. Parr Rosson, III. "*An Assessment of the Global Soybean Industry: An Application of Stochastic Equilibrium Displacement Model.*" Paper presented at the SAEA Meeting, February 4-7, 2007, Mobile, Alabama.
- **Rafael F. Costa** and C. Parr Rosson, III. "*Decreasing Brazil's Transportation Costs through Improvement in Infrastructure: A General Equilibrium Analysis on the Soybean Complex World Market*". Accepted for presentation at the Food Distribution Research Society (FDRS) Conference, October 14-18, 2006, Quebec City, Canada.

**WORKING EXPERIENCE**

- Center for North American Studies (CNAS), Department of Agricultural Economics, Texas A&M University, College Station, TX: Graduate Research Assistant. September 1, 2005 – present.
- Department of Economics, Federal University of Pernambuco (UFPE), Recife, Pernambuco, Brazil: Research Assistant. August 1, 2003 – July 31, 2005.